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Characteristics of FACTORY-GRADE HARDWOOD LOGS Delivered to Appalachian Sawmills

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by Curtis D. Goho
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NORTHEASTERN FOREST EXPERIMENT STATION, UPPER DARBY, PA.
FOREST SERVICE, U. S. DEPARTMENT OF AGRICULTURE
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survey data. Researchers may find the data helpful when they need a foreknowledge of sample size in order to plan a study.

APPLICABILITY OF DATA

The graphs in this paper illustrate how the diameters, lengths, grades, and volumes of factory-grade hardwood sawlogs are distributed for the various Appalachian species sampled. Although these graphs are based on numbers of logs, the increments on the vertical axes of all graphs are in percent—not numbers of logs. This does not change general graphic shapes, and it does allow a direct comparison between species by eliminating the variation due to sample size.

Although the frequency distributions can be a valuable working tool, they have limitations that must be considered. First, the distributions represent factory-grade logs only. Construction grade, local-use, and cull logs were omitted, for they accounted for less than 2 percent of the logs sampled. Second, none of the graphs will precisely represent the logs received at any individual mill. Nor will the data necessarily apply to a small sample of logs received over a short period of time. However, even though there may be substantial deviations in any particular size and quality class, the general trends should be representative of long-term factory-grade log receipts.

The following factors will help you to evaluate the significance and applicability of the frequency distributions:

- 4,386 logs were measured.
- Species were recorded in nine groups: red oak, white oak, chestnut oak, beech, birch, maple, ash-basswood, poplar-cucumber, and miscellaneous. The red-oak group included red, scarlet, and black oaks; the birch group included yellow and black birch; the maple group included red and sugar maples; and the miscellaneous group contained mainly hickory and black cherry.
- Logs were measured at 15 sawmills scattered through five states: North Carolina, Virginia, West Virginia, Massachusetts and Vermont.

- Only 17 percent of the sample was taken in New England; most of the logs were sampled in West Virginia. The logs sampled in New England had slightly less volume than logs of similar species sampled in the southern Appalachians.
- 48 percent of the logs were delivered to circular sawmills, and the rest were delivered to band mills. The logs delivered to circular mills were similar in size and grade to those delivered to band mills.

DIAMETER AND GRADE DISTRIBUTIONS

The logs were concentrated heavily in the smaller diameters (figs. 1 to 9). For most species, the graphed frequency distributions rise rapidly in the lower diameters, peak at 12 to 14 inches, decline sharply at 17 or 20 inches, and then trail off gradually. Except for chestnut oak and beech, two-thirds of the logs had scaling diameters of less than 16 inches.

The tables accompanying the graphs show the distribution of logs among the three factory grades established by the USDA Forest Service.[1] For most species, high-quality grade-1 logs made up less than 20 percent of the total. Conversely, one-third or more of the logs of most species were grade 3. Most of the logs in most species were grade 2 logs having potential lumber yields of 30 to 60 percent in grades 1 Common and Better.[2]

Log quality was closely linked to scaling diameter. For most species, most logs 11 inches in diameter and smaller were grade 3. Most of the logs between 12 and 16 inches in diameter were grade 2. And for most species, most logs 17 inches in diameter and larger were grade 1.

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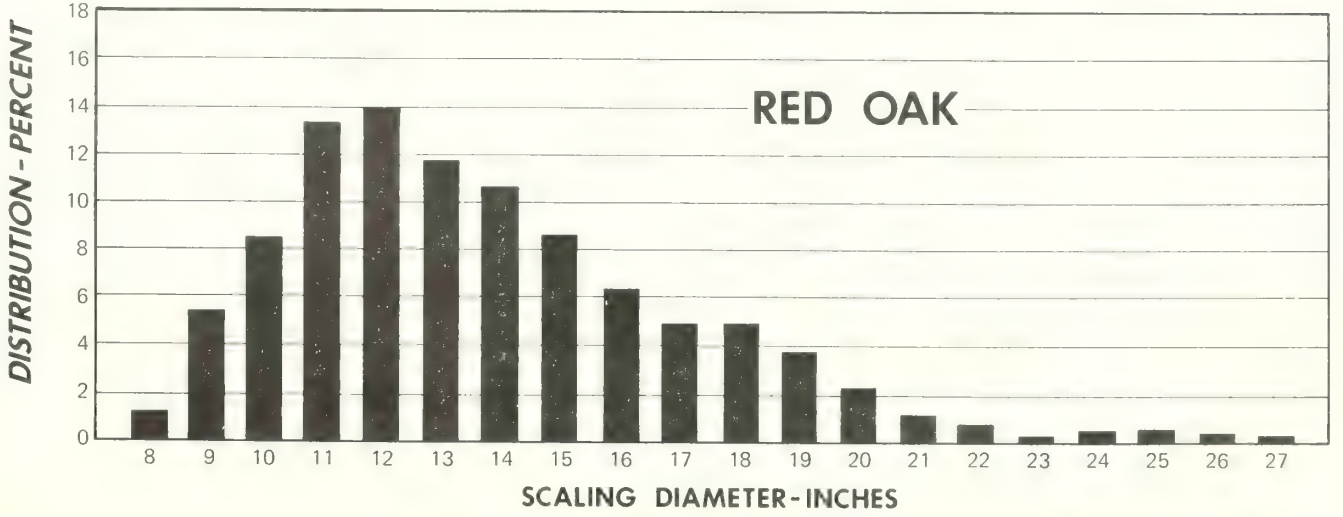
[1] Ostrander, M. D., and others. A GUIDE TO HARDWOOD LOG GRADING (REVISED). USDA Forest Serv. NE. Forest Exp. Sta., 50 pp., illus. Upper Darby, Pa. 1965.

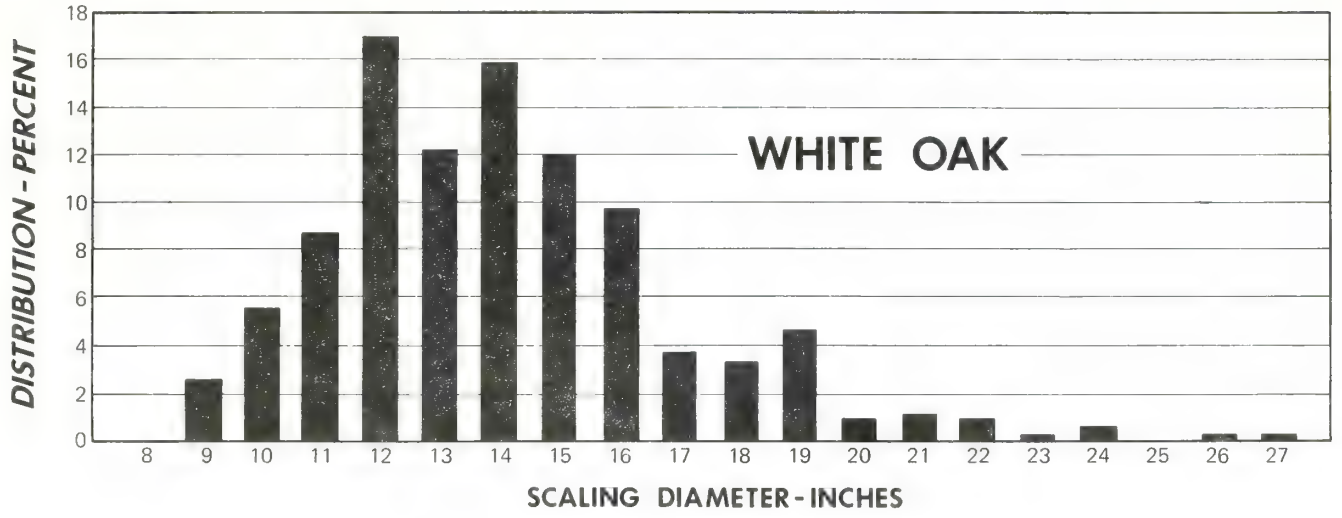
[2] Vaughan, C. L., A. C. Wollin, K. A. McDonald, and E. H. Bulgrin. HARDWOOD LOG GRADES FOR STANDARD LUMBER. USDA Forest Serv. Res. Paper FPL-63, 52 pp., illus. Forest Prod. Lab., Madison, Wis. 1966.

Figure 1.—Distribution of factory-grade sawlogs among diameter classes and log grades (958-log sample).



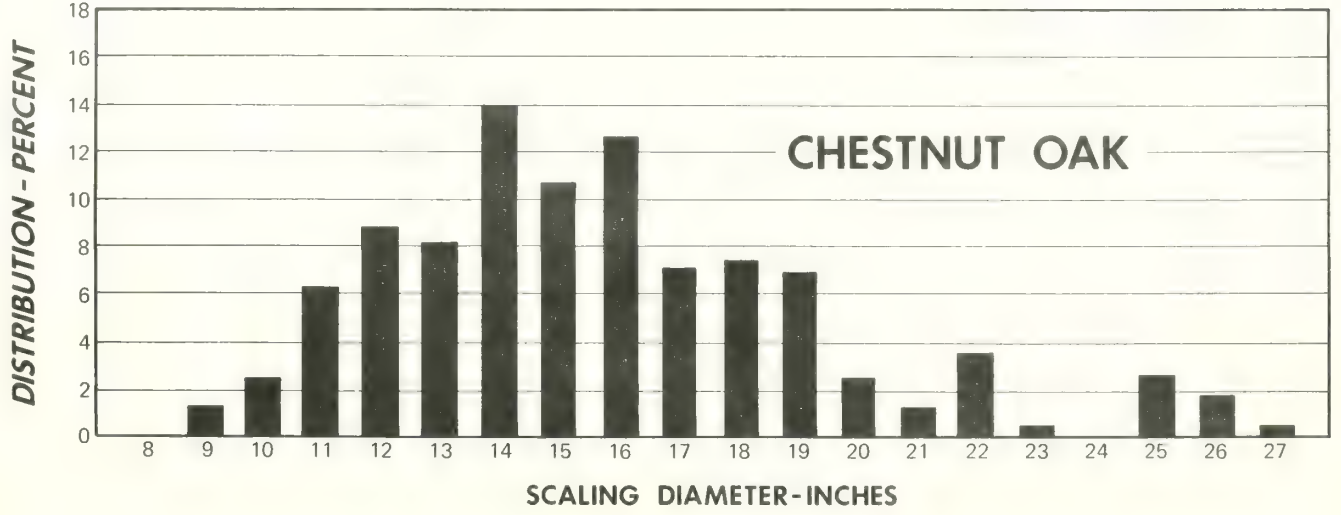
	LOG-GRADE DISTRIBUTION-PERCENT																				TOTAL
GRADE 1	--	--	--	--	--	3.6	2.1	2.9	2.5	1.9	2.6	2.3	1.1	0.7	0.3	0.2	0.3	0.2	0.4	0.1	21.2
GRADE 2	--	--	1.3	6.6	10.0	4.9	6.2	3.5	2.5	2.1	1.5	1.0	1.0	.3	0	0	.2	.1	0	.2	41.4
GRADE 3	1.3	5.4	7.1	6.8	4.0	3.3	2.3	2.3	1.3	.9	.8	.5	.1	.2	.5	.1	.1	.4	0	0	37.4
TOTAL	1.3	5.4	8.4	13.4	14.0	11.8	10.6	8.7	6.3	4.9	4.9	3.8	2.2	1.2	0.8	0.3	0.6	0.7	0.4	0.3	100.0

Figure 2.—Distribution of factory-grade sawlogs among diameter classes and log grades (343-log sample).



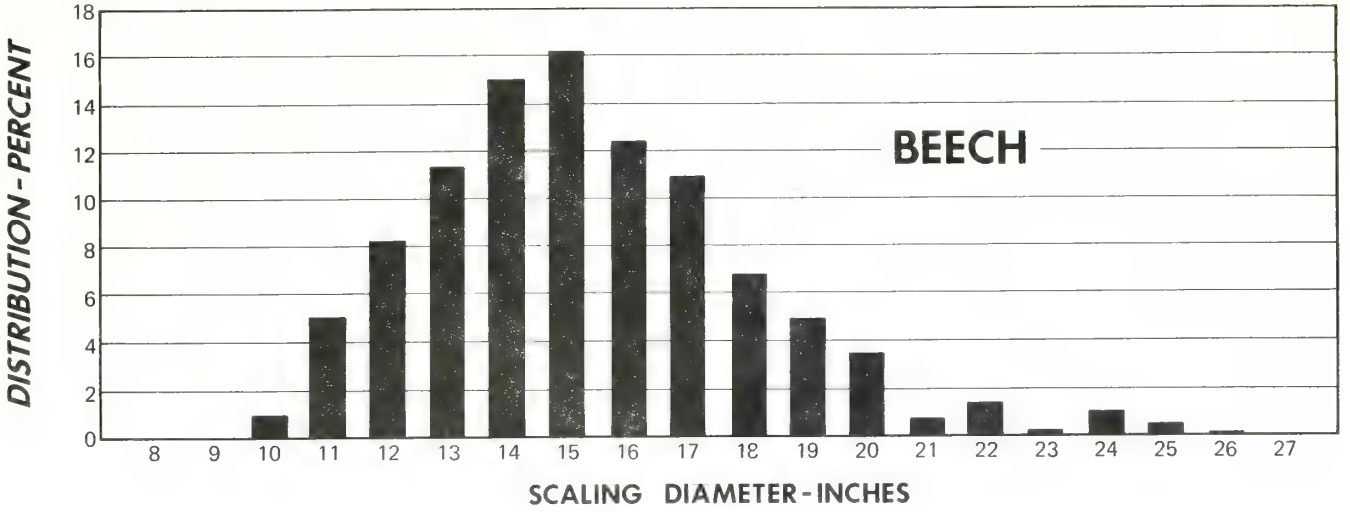
	LOG-GRADE DISTRIBUTION - PERCENT																				TOTAL
GRADE 1	--	--	--	--	--	2.7	2.6	3.2	2.0	1.2	1.5	1.7	0.6	0.3	0.9	0	0.6	0	0	0	17.3
GRADE 2	--	--	2.1	2.6	7.2	4.3	5.5	4.2	4.9	1.9	.9	1.7	.3	.6	0	0	0	0	0.3	0	36.6
GRADE 3	0	2.6	3.5	6.1	9.8	5.2	7.8	4.6	2.9	.6	.9	1.2	0	0.3	0	0.4	0	0	0	0.3	46.1
TOTAL	0	2.6	5.6	8.7	17.0	12.2	15.9	12.0	9.8	3.7	3.3	4.6	0.9	1.2	0.9	0.4	0.6	0	0.3	0.3	100.0

Figure 3.—Distribution of factory-grade sawlogs among diameter classes and log grades (158-log sample).



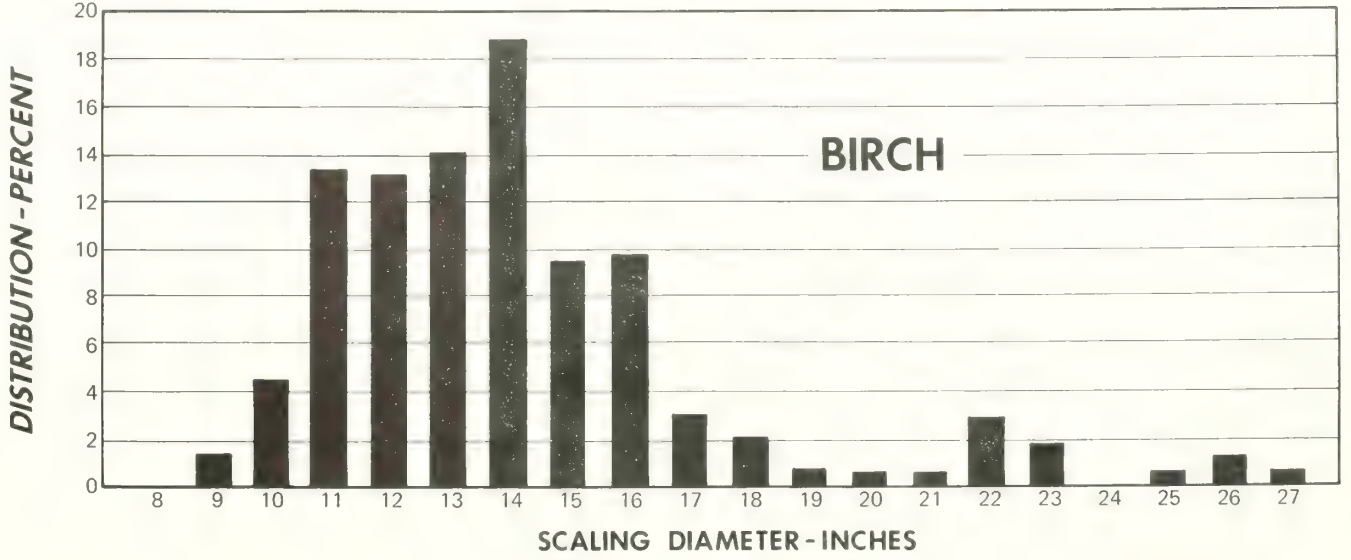
	LOG-GRADE DISTRIBUTION-PERCENT																				TOTAL
GRADE 1	--	--	--	--	--	0	1.3	0.6	3.2	3.8	3.2	5.7	1.9	1.3	1.9	0	0	1.3	0.6	0.6	25.4
GRADE 2	--	--	0	2.5	5.7	5.7	8.9	6.3	7.0	1.9	3.2	.6	.6	0	1.9	0.6	0	1.3	1.3	0	47.5
GRADE 3	0	1.3	2.5	3.8	3.2	2.5	3.8	3.8	2.4	1.9	1.3	.6	0	0	0	0	0	0	0	0	27.1
TOTAL	0	1.3	2.5	6.3	8.9	8.2	14.0	10.7	12.6	7.6	7.7	6.9	2.5	1.3	3.8	0.6	0	2.6	1.9	0.6	100.0

Figure 4.—Distribution of factory-grade sawlogs among diameter classes and log grades (346-log sample).



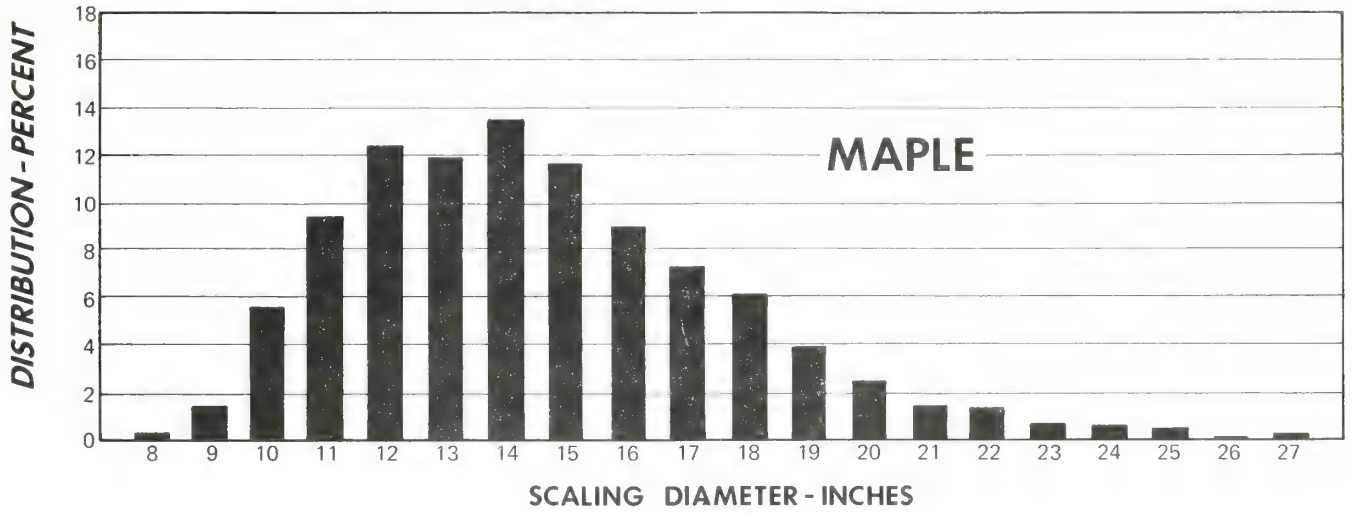
	LOG-GRADE DISTRIBUTION - PERCENT																				TOTAL
GRADE 1	--	--	--	--	--	2.6	1.2	2.9	2.9	2.6	1.2	1.7	1.4	0	0.6	0	0.6	0.6	0	0	18.3
GRADE 2	--	--	0	1.4	3.6	5.2	7.8	7.2	4.9	6.4	2.6	2.3	1.4	0.9	.6	0.3	.6	0	0	0	45.2
GRADE 3	0	0	1.2	3.6	4.6	3.5	6.1	6.1	4.6	2.0	2.9	.9	.6	0	.3	0	0	0	0.1	0	36.5
TOTAL	0	0	1.2	5.0	8.2	11.3	15.1	16.2	12.4	11.0	6.7	4.9	3.4	0.9	1.5	0.3	1.2	0.6	0.1	0	100.0

Figure 5.—Distribution of factory-grade sawlogs among diameter classes and log grades (135-log sample.)



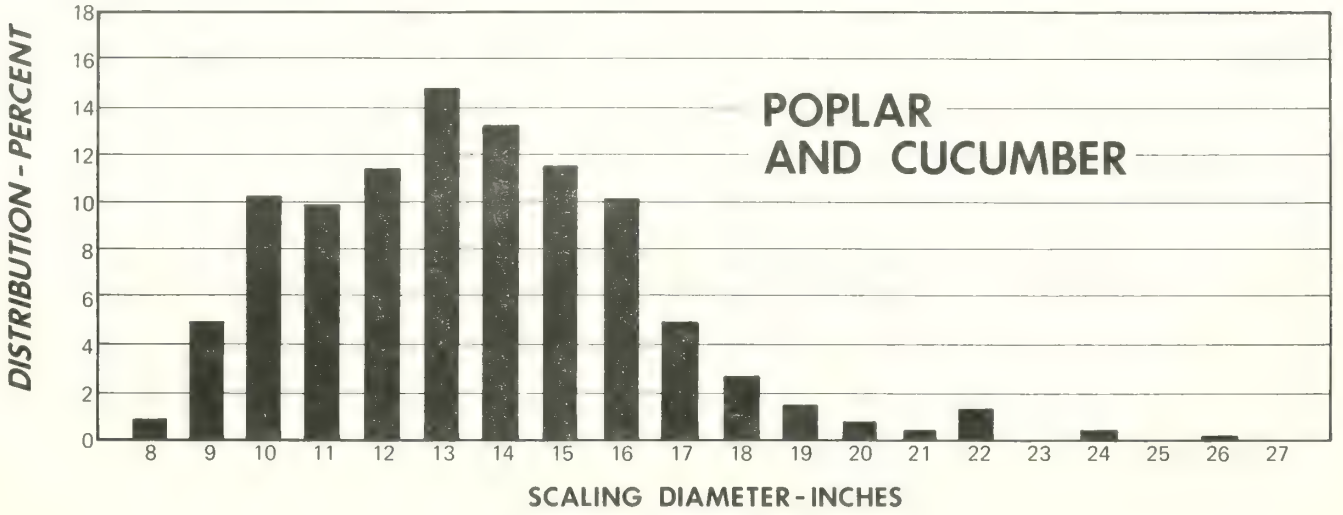
	LOG-GRADE DISTRIBUTION - PERCENT																				TOTAL
GRADE 1	--	--	--	--	--	3.0	5.2	1.5	3.7	2.4	0.7	0	0	0	1.5	0.9	0	0	0.7	0	19.6
GRADE 2	--	--	0	6.7	5.9	8.1	9.6	7.4	4.4	.7	1.5	0.9	0.7	.7	.7	0	0	0.7	.7	0.7	49.4
GRADE 3	0	1.5	4.4	6.7	7.4	3.0	4.0	.7	1.7	0	0	0	0	0	.7	.9	0	0	0	0	31.0
TOTAL	0	1.5	4.4	13.4	13.3	14.1	18.8	9.6	9.8	3.1	2.2	0.9	0.7	0.7	2.9	1.8	0	0.7	1.4	0.7	100.0

Figure 6.—Distribution of factory-grade sawlogs among diameter classes and lag grades (1,170-log sample).



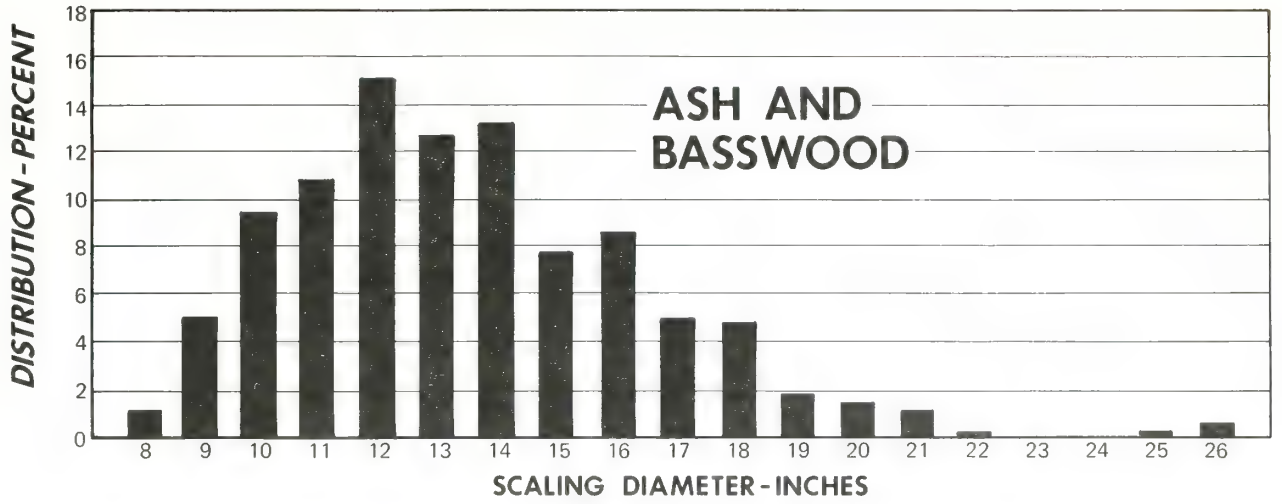
	LOG-GRADE DISTRIBUTION - PERCENT																				TOTAL
GRADE 1	--	--	--	--	--	1.4	1.6	2.4	2.4	1.7	1.9	1.7	0.8	0.8	0.6	0.4	0.3	0.1	0	0.1	16.2
GRADE 2	--	--	0.1	4.8	6.8	6.1	7.3	5.8	4.0	3.5	2.2	1.4	1.5	.4	.5	.1	.2	.1	0.1	.1	45.0
GRADE 3	0.3	1.4	5.6	4.7	5.6	4.4	4.6	3.5	2.6	2.1	2.0	.8	.3	.2	.2	.2	.1	.2	0	0	38.8
TOTAL	0.3	1.4	5.7	9.5	12.4	11.9	13.5	11.7	9.0	7.3	6.1	3.9	2.6	1.4	1.3	0.7	0.6	0.4	0.1	0.2	100.0

Figure 7.—Distribution of factory-grade sawlogs among diameter classes and log grades (427-log sample).



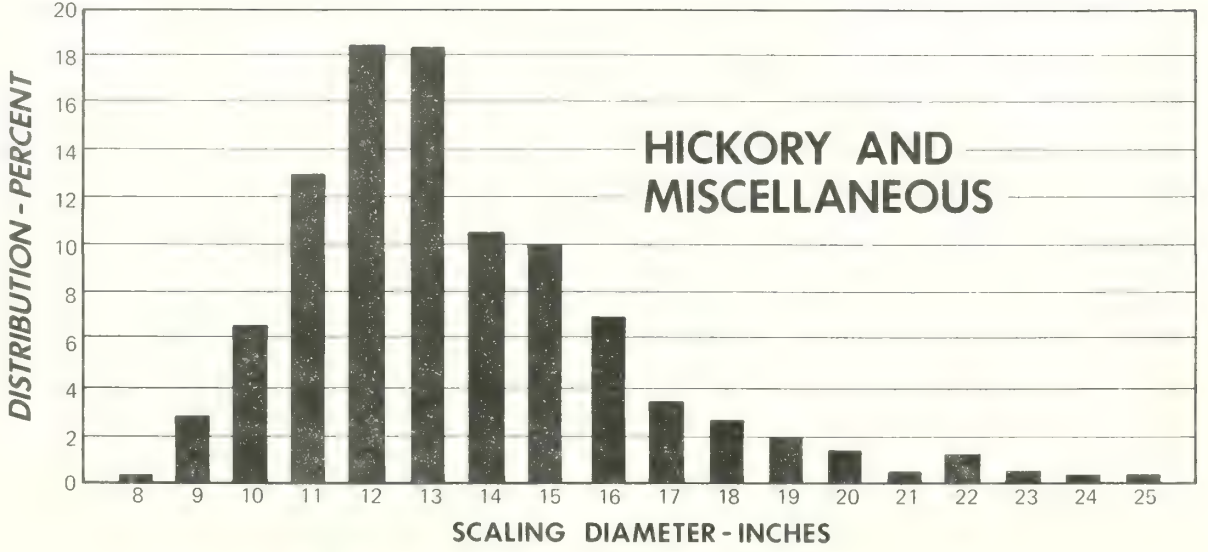
	LOG-GRADE DISTRIBUTION-PERCENT																			TOTAL
GRADE 1	--	--	--	--	--	1.6	3.3	2.6	6.8	2.1	1.4	0.7	0.4	0.2	0.7	0	0.4	0	0.2	0 20.4
GRADE 2	--	--	0	4.9	6.8	8.4	8.4	6.8	3.0	1.9	1.4	.9	.2	.2	0	0	0	0	0	0 42.9
GRADE 3	0.9	4.9	10.3	4.9	4.7	4.9	1.6	2.3	.4	.9	0	0	.2	0	.7	0	0	0	0	0 36.7
TOTAL	0.9	4.9	10.3	9.8	11.5	14.9	13.3	11.7	10.2	4.9	2.8	1.6	0.8	0.4	1.4	0	0.4	0	0.2	0 100.0

Figure 8.—Distribution of factory-grade sawlogs among diameter classes and log grades (315-log sample).



	LOG-GRADE DISTRIBUTION-PERCENT																			TOTAL
GRADE 1	--	--	--	--	1.9	4.1	3.2	2.5	3.2	2.5	3.2	1.6	1.3	1.3	0.3	0	0	0.3	0.3	25.7
GRADE 2	--	--	0.9	7.0	9.2	5.1	7.6	4.4	3.8	1.9	1.3	0	.3	0	0	0	0	0	.3	41.8
GRADE 3	1.3	5.1	8.6	3.8	4.1	3.5	2.5	.8	1.6	.6	.3	.3	0	0	0	0	0	0	0	32.5
TOTAL	1.3	5.1	9.5	10.8	15.2	12.7	13.3	7.7	8.6	5.0	4.8	1.9	1.6	1.3	0.3	0	0	0.3	0.6	100.0

Figure 9.—Distribution of factory-grade sawlogs among diameter classes and log grades (534-log sample).



	LOG - GRADE DISTRIBUTION - PERCENT																		TOTAL
GRADE 1	--	--	--	--	--	3.5	2.2	3.4	1.9	1.5	0.6	0.9	0.6	0.2	0.9	0.4	0.2	0.2	16.5
GRADE 2	–	–	0.6	6.4	9.6	8.4	5.4	4.9	2.8	1.3	1.3	.4	.7	.4	.2	0	.2	.2	42.8
GRADE 3	0.4	2.8	6.0	6.7	8.8	6.4	3.0	1.7	2.2	.7	.7	.7	.2	0	.2	.2	0	0	40.7
TOTAL	0.4	2.8	6.6	13.1	18.4	18.3	10.6	10.0	6.9	3.5	2.6	2.0	1.5	0.6	1.3	0.6	0.4	0.4	100.0

The distributions of log lengths were similar among most of the nine species groups that were sampled (figs. 10, 11, and 12). The percentage of logs cut to different lengths increased progressively as lengths increased from 8 feet to 12 feet. Except for the poplar-cucumber log group, more logs were cut to 12-foot lengths than to any of the other lengths. The straight bole characteristics of poplar and cucumber may account for the predominance of 16-foot logs cut from these species.

Except for the oak log groups, there were noticeably fewer 14-foot logs than 12- and 16-foot logs. Evidently buckers have learned that logs that are straight enough for 14-foot lengths can usually be extended to 16 feet without noticeable scaling penalty. Furthermore, logging contractors favor 16-foot logs because of greater trucking efficiency. Sawmill operators also prefer 16-foot logs to 14-foot logs if the longer logs are reasonably straight. So the production of fewer 14-foot logs may be more a matter of economics and policy than a function of stem shape.

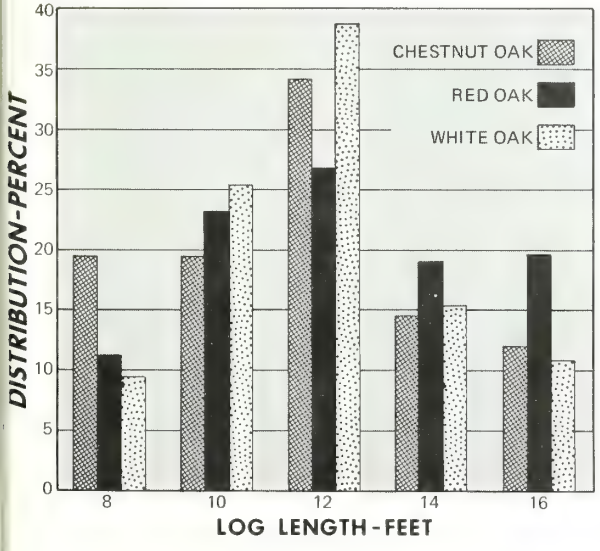
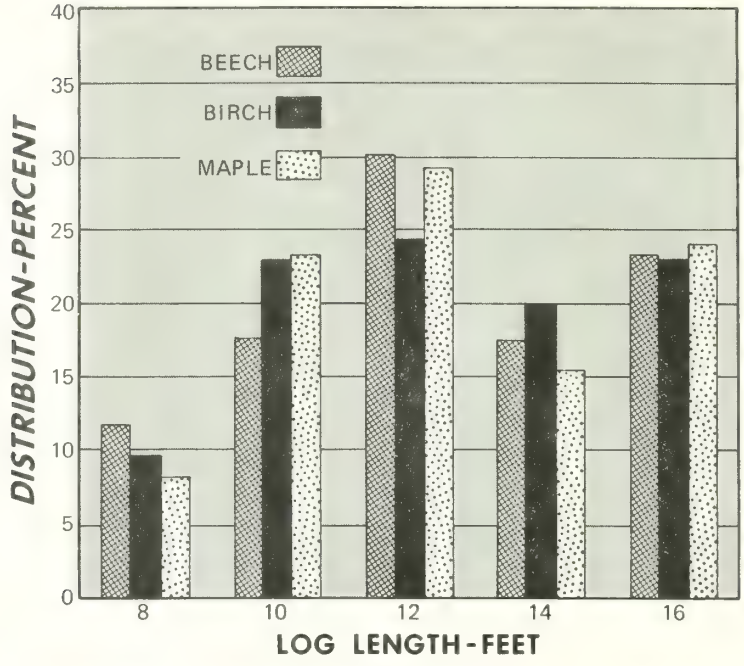


Figure 10. — Distribution (by percent of total for each species) of sawlog lengths observed at sample mills.

Figure 11.—Distribution (by percent of total for each species) of sawlog lengths observed at sample mills.



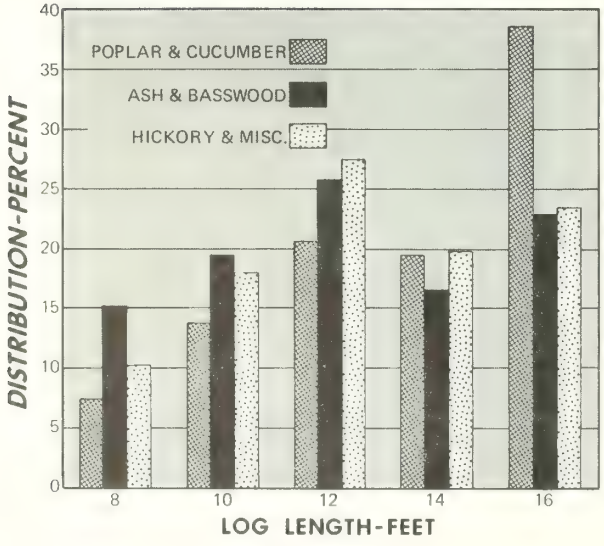


Figure 12. — Distribution (by percent of total for each species) of sawlog lengths observed at sample mills.

LOG-VOLUME DISTRIBUTIONS

Curves showing the proportionate number of logs by volume classes (figs. 13, 14, and 15) may be more useful than the frequency distributions by diameters and lengths, because volume is a function of both of these elements. The volume classes used to develop these curves were: 20 board feet or less, 21 to 40, 41 to 60, 61 to 80, 81 to 100, 101 to 150, 151 to 200, 201 to 250, 251 to 300, 301 to 400, and over 400 board feet.

The cumulative curves provide: (1) the gross log scale representing a specified portion of a species sample and (2) the portion of the total species sample above or below a selected log scale. For example, the index lines linked to the red-oak curve (fig. 13) show that 50 percent of the logs had a gross scale less than 60 board feet, Doyle. Index lines linked to the chestnut-oak curve (fig. 13) show that logs scaling 150 board feet or less accounted for about 75 percent of the total sample in this species.

Figure 13.—Relationship between individual log scale and the cumulative percent of the total number of logs sampled for each species.

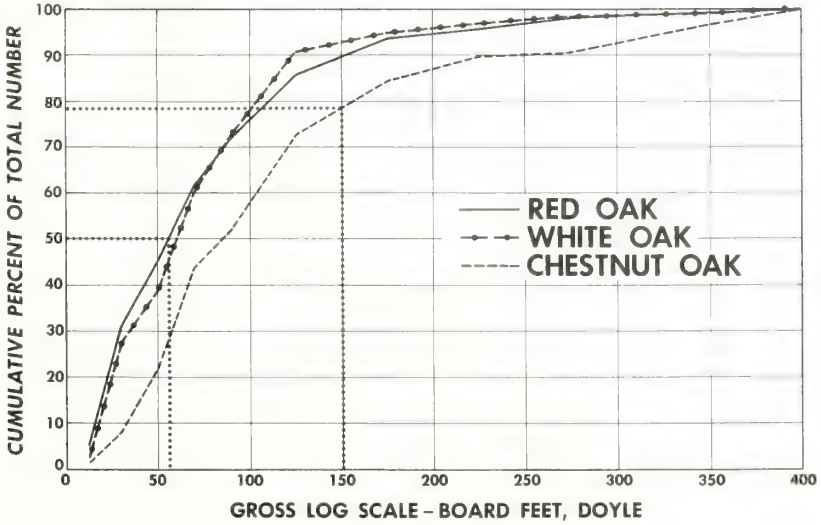


Figure 14.—Relationship between individual log scale and the cumulative percent of the total number of logs sampled for each species.

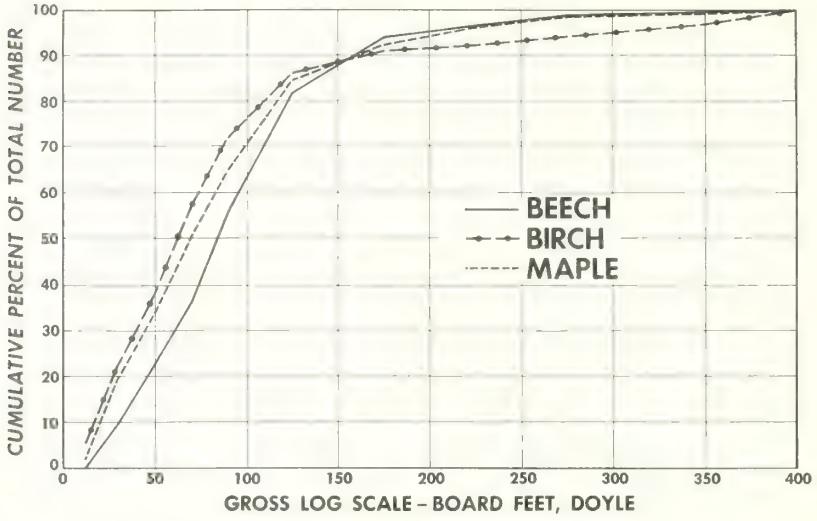
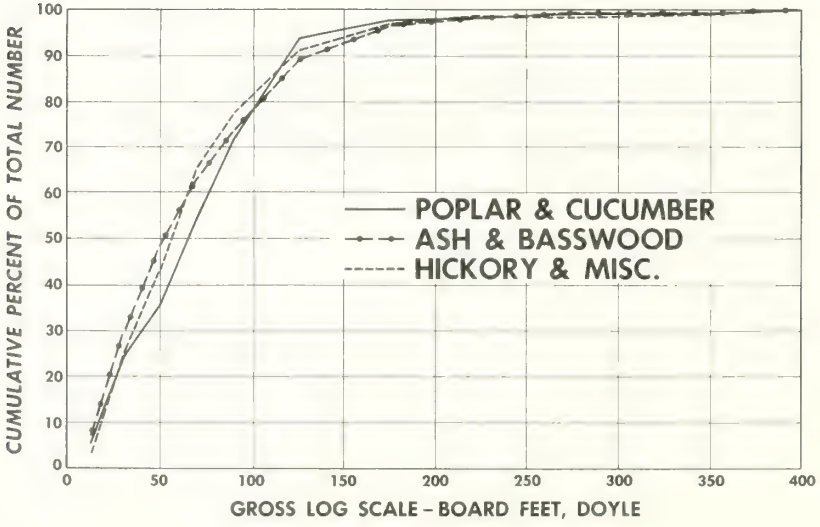


Figure 15.—Relationship between individual log scale and the cumulative percent of the total number of logs sampled for each species.



In skewed distributions like those shown in this paper, median volume is a more reliable measure of the midpoint than average log volume. Median volumes describes that point in the cumulative curve where there are as many logs with a larger volume as there are with a smaller volume. Mill operators should use the median for a measure of production efficiency rather than use the average. Median volumes (board feet, Doyle) for the log samples used in this study are as follows:

Species group	*Median log volume*
Red oak	70
White oak	70
Chestnut oak	95
Beech	95
Birch	70
Maple	80
Ash-basswood	65
Poplar-cucumber	75
Miscellaneous	65

The size, grade, and volume frequencies presented in this paper show general trends only—not exact profiles of the saw-log distributions that can be expected at any sawmill. For the greatest precision, we urge sawmill operators to develop their own frequency distributions. Scale-book records can be plotted to give a good picture of raw material inputs.

■

THE FOREST SERVICE of the U. S. Department of Agriculture is dedicated to the principle of multiple use management of the Nation's forest resources for sustained yields of wood, water, forage, wildlife, and recreation. Through forestry research, cooperation with the States and private forest owners, and management of the National Forests and National Grasslands, it strives — as directed by Congress — to provide increasingly greater service to a growing Nation.

Quality Index Tables
for Some Eastern Hardwood Species

by Joseph J. Mendel
and William H. Smith

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NORTHEASTERN FOREST EXPERIMENT STATION, UPPER DARBY, PA.
FOREST SERVICE, U.S. DEPARTMENT OF AGRICULTURE
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Quality Index Tables for Some Eastern Hardwood Species

Another Use for Q. I.

EVER SINCE the quality-index (Q.I.) concept was introduced by A. M. Herrick in 1946, its importance as a measure of timber value has grown; and it has been used, not only in other research efforts, but also as a tool to be used by foresters and timber operators *(Herrick 1946)*.

We have recently employed the Q.I. concept in our rate-of-value-increase studies on nine tree species in the Northeast and recognized that, as a byproduct of this study, the log-quality indexes would be useful to timber operators.

This paper briefly reviews the quality-index concept, presents log-quality index tables for a selected group of eastern hardwood tree species, and explains how timber operators can use Q.I. for evaluating the lumber that can be sawed from logs and trees.

The Q.I. tables are based on two different lumber price reporting services and cover different geographic regions. Those species that occur in more than one region have a different Q.I. in each region.

What Q. I. Is

Quality index is a single number that expresses the relative value of a log as determined by the value of the different grades of 4/4 lumber (1-inch thick) that can be sawed from the log. In formula form *(Herrick 1956)* it appears as:

$$\text{Q.I.} = (\%\ \text{FAS} \times \text{P.R.}_{\text{FAS}}) + (\%\ \text{SEL} \times \text{P.R.}_{\text{SEL}}) + (\%\ \text{No. 1C} \times \text{P.R.}_{\text{No. 1C}}) + \cdots\cdots (\%\ \text{No. 3A} \times \text{P.R.}_{\text{3A}})$$

in which % FAS means the percentage of the total volume of lumber that could be sawed from the log that would grade First and Second, and P.R. $_{\text{FAS}}$ means the standard price relative for FAS lumber.

Thus two sets of data are necessary for developing Q.I.: (1) lumber grade yields by log grade, log diameter, and species; and (2) lumber price relatives, that is, price ratios with No. 1 Common as the base grade as derived from applicable regional price reports and averaged for a period of 5 years.

In this analysis, USDA Forest Service log grades for hardwood factory lumber logs of grades 1, 2, and 3 were used *(Ostrander et al. 1965)*.

Lumber-grade yield estimates were obtained from the USDA Forest Products Laboratory publication *Hardwood Log Grades for Standard Lumber (Vaughn et al. 1966)*. The erratic nature of the basic data, especially in the larger diameter classes, made it necessary to hand-curve the yield data to make them useful for developing the Q.I.'s.

Lumber price relatives used here were developed from prices derived from the *Hardwood Market Report (Lemsky 1964-1968)* and *The Commercial Bulletin* (Curtis Guild and Co. Publishers, Inc.) for the base period, 1964-1968. Prices were averaged over the 5-year period; and the price relatives, that is, the average price of the various grades relative to the average price of No. 1 Common lumber, were determined. The price relative (P.R.) for No. 1 Common is always 1.00, whereas the P.R.'s for hardwood lumber grades FAS and SEL are above 1.00 and the P.R.'s for No. 2 Common, No. 3A Common, and No. 3B Common are below 1.00 (table 1).

Table 1.—Lumber price relatives by grade and species

(Basis: 4/4 No. 1 COMMON, the reference grade)

Species	Lumber grade							
	FAS	SEL	SAPS	No. 1C	No. 2C No. 2A	No. 2B	No. 3A	No. 3B
White ash	1.63	1.56	.	1.00	0.53		0.44	0.39
Beech	1.25	1.18	.	1.00	.54	. .	.42	.38
Black cherry	1.45	1.40	. .	1.00	.46	.	.27	.25
Hard maple	1.53	1.47		1.00	.44		.38	.27
Soft maple	1.28	1.23	.	1.00	.47		.43	.30
Red oak	1.65	1.57		1.00	.64	. .	.56	.37
White oak	1.82	1.74		1.00	.66		.58	.39
Yellow-poplar	1.42	1.36	1.29	1.00	.67	0.45	.23	.23

Based on 1964-68 prices from *Hardwood Market Report* for Appalachian hardwoods, f.o.b. mills, Johnson City, Tennessee area.

White ash	1.61	1.52	.	1.00	0.50		0.40	0.35
Beech	1.24	1.17	.	1.00	.53	.	.42	.38
Black cherry	1.44	1.38		1.00	.45		.26	.24
Hard maple	1.49	1.45	. .	1.00	.46	. .	.40	.29
Red oak	1.63	1.55	. .	1.00	.62	. . .	.54	.35
White oak	1.80	1.73	. .	1.00	.64	.	.56	.37
Yellow-poplar	1.41	1.34	1.29	1.00	.67	0.45	.23	.23

Based on 1964-68 prices from *The Commercial Bulletin,* Appalachian area. Prices included wholesale commission and are f.o.b. mill, rough and air-dried.

White ash	1.53	1.40	. . .	1.00	0.46	. .	0.36	0.32
Beech	1.33	1.17		1.00	.56	.	.43	. 39
Birch	1.70	1.60	. . .	1.00	.54	.	.46	.28
Hard maple	1.57	1.44	. .	1.00	.60		.52	.41
Soft maple	1.33	1.23	. .	1.00	.47	.	.39	.30
Oak	1.54	1.36	. . .	1.00	.77	. . .	.69	.50

Based on 1964-68 prices from *The Commercial Bulletin,* Northeastern area. Prices included wholesale commission and are f.o.b. mill, rough and air-dried.

Once the lumber grade yields and price relative are obtained, it is possible to calculate the Q.I.'s. For example, given a white ash log of 16-inch diameter inside bark, log grade No. 1, with lumber grade yields of 41.4 percent FAS, 11.0 percent SEL, 26.5 percent No. 1C, 12.3 percent No. 2C, 4.4 percent No. 3A, and 4.4 percent No. 3B, and the price relative as shown in table 1 for white ash, the Q.I. calculation appears as:

$$\text{Q.I.} = (.414 \times 1.63) + (.110 \times 1.56) + (.265 \times 1.00) + (.123 \times 0.53) + (.044 \times 0.44) + (.044 \times 0.39)$$
$$\text{Q.I.} = 1.21$$

Log Q.I.'s were computed for each species and diameter for log grades No. 1, No. 2, and No. 3 (tables 2 to 22). For log classes below these grades, lumber grade yields were not available; so log Q.I.'s were not calculated.

What Q.I. Does

Log-quality indexes are useful in estimating the value of lumber in a log. All that is needed to determine the lumber value are the Q.I. and the current price of 4/4 No. 1 Common lumber. For example, assume that a log buyer wants to know the value of standard lumber he can expect to saw from a 16-inch diameter, 16-foot long, grade No. 1 white ash log. Such a log has a volume of 180 board feet (International $\frac{1}{4}$-inch log rule). Table 2 shows that the log Q.I. value is 1.21. The only additional information needed is the current selling price of 4/4 No. 1 Common white ash. The buyer can use the price his mill is receiving, or he can refer to one of the lumber price reports. If, for example, the current price for No. 1 Common white ash lumber is $230 per thousand board feet (quoted in the October 11, 1969, issue of the *Hardwood Market Report for Appalachian Hardwoods*), it is a simple matter to calculate the expected lumber value of the log by using the formula:

$$\text{Lumber product value} = (\text{Q.I.}) \times (\text{Price of 4/4 No. 1C}) \times \frac{\text{volume of log}}{1000}$$
$$= (1.21) \times (\$230) \times \frac{180}{1000}$$
$$= \$50.09$$

The buyer can expect to receive about $50 from the 4/4 standard lumber that could be sawed from this white ash log.

Putting Q.I. To Work

Quality index is a versatile tool. It permits a ready evaluation of a log or tree on the basis of the grade and amount of lumber that can be sawed from the log or tree. It has been widely used in research to develop economic guides for hardwood sawtimber management. However, its most basic application is in log or tree evaluation as done by practicing foresters and timber buyers. It can be used in timber appraisals where more than a cursory volume estimate is needed. Further, it can be employed with efficiency in the log yard.

Several factors should be recognized when using log-quality indexes.

1. Lumber price relatives are developed from the 5-year average price of various lumber grades, based on 4/4 No. 1 Common as the reference grade. Therefore, any fluctuations in standard lumber prices will affect the price relative values. Should there be any major price changes, especially between lumber grades, it might be well to develop price relatives by using prices based on the latest 5-year period.

2. When using the quality index one must recognize that the Q.I. evaluation is based on the assumption that the log is sawed into 4/4 lumber, in an adequate mill, by a sawyer skilled in cutting standard graded hardwood lumber. Few, if any, mills saw only 4/4 lumber, so the Q.I.'s are only a close approximation. However, a method for adjusting Q.I.'s has been developed (Research Paper NE-149, *Adjusting Quality Index Log Values to Represent Local and Regional Commercial Sawlog Product Values*). Such adjustments should result in Q.I.'s that will account for the inherent variances between the actual production of a specific mill and the assumed 4/4 lumber production of the so-called "adequate" mill.

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Appendix

Tables 2 to 9 are based on 1964-68 lumber prices from the *Hardwood Market Report, Appalachian Area,* tables 10 to 16 are based on 1964-68 lumber prices from *The Commercial Bulletin, Appalachian Area,* and tables 17 to 22 are based on 1964-68 lumber prices from *The Commercial Bulletin, Northeastern Area.*

Table 2.—Log-quality index for **WHITE ASH** by log grade or class and size class [1]

Log diameter inside bark (inches)	Quality index		
	Log grade No. 1	Log grade No. 2	Log grade No. 3
8	. . .	. . .	0.60
9	. . .	. . .	.61
10	. . .	0.84	.63
11	. . .	.87	.66
12	1.12	.89	.69
13	1.14	.92	.72
14	1.17	.95	.76
15	1.19	.97	.80
16	1.21	1.00	.84
17	1.23	1.02	.88
18	1.25	1.05	.92
19	1.27	1.08	.96
20	1.29	1.10	1.00
21	1.31	1.12	1.04
22	1.33	1.14	1.08
23	1.35	1.16	1.11
24	1.37	1.18	1.14

[1] Data in tables 2-9 were derived by hand-curving lumber grade yield data from USDA Forest Serv. Res. Paper FPL-63 and 1964-68 lumber prices from *Hardwood Market Report, Appalachian Area.*

Table 3.—Log-quality index for **BEECH** by log grade or class and size class

Log diameter inside bark (inches)	Quality index		
	Log grade No. 1	Log grade No. 2	Log grade No. 3
8	. . .	. . .	0.49
9	. . .	. . .	.50
10	. . .	0.64	.51
11	. . .	.65	.52
12	. . .	.67	.53
13	0.82	.68	.55
14	.84	.71	.56
15	.87	.73	.58
16	.88	.74	.60
17	.89	.75	.62
18	.90	.77	.63
19	.90	.78	.66
20	.91	.79	.68
21	.92	.80	.70
22	.92	.81	.73
23	.92	.82	.76
24	.92	.82	.79
25	.93	.83	.81

Table 4.—Log-quality index for **BLACK CHERRY** by log grade or class and class size

Log diameter inside bark (inches)	Quality index		
	Log grade No. 1	Log grade No. 2	Log grade No. 3
8	. . .	. . .	0.41
9	. . .	. . .	.47
10	. . .	0.74	.52
11	. . .	.77	.55
12	. . .	.80	.59
13	1.08	.83	.63
14	1.09	.86	.67
15	1.10	.89	.73
16	1.11	.91	.77
17	1.11	.94	.82
18	1.13	.96	.85
19	1.14	.98	.87
20	1.16	1.00	.89
21	1.18	1.02	.90
22	1.20	1.05	.91
23	1.22	1.08	.92
24	1.25	1.11	.93
25	1.27	1.14	.94

Table 5.—Log-quality index for **HARD MAPLE** by log grade or class and size class

Log diameter inside bark (inches)	Quality index		
	Log grade No. 1	Log grade No. 2	Log grade No. 3
8	. . .	. . .	0.45
9	. . .	. . .	.45
10	. . .	0.63	.45
11	. . .	.65	.46
12	. . .	.67	.46
13	0.99	.68	.46
14	.99	.71	.47
15	.99	.73	.47
16	1.01	.75	.47
17	1.02	.78	.49
18	1.02	.79	.50
19	1.03	.81	.52
20	1.05	.83	.55
21	1.07	.86	.57
22	1.09	.88	.59
23	1.11	.91	.61
24	1.13	.93	.63
25	1.15	.96	.65
26	1.17	.98	.67

Table 6.—Log-quality index for **RED OAK** by log grade or class and size class

Log diameter inside bark (inches)	Quality index		
	Log grade No. 1	Log grade No. 2	Log grade No. 3
8	. . .	. . .	0.54
9	. . .	. . .	.55
10	. . .	0.77	.55
11	. . .	.78	.55
12	. . .	.79	.55
13	1.02	.80	.56
14	1.09	.81	.56
15	1.12	.82	.56
16	1.15	.83	.56
17	1.16	.83	.57
18	1.16	.83	.59
19	1.16	.83	.61
20	1.16	.83	.63
21	1.16	.83	.66
22	1.16	.84	.69
23	1.16	.84	.72
24	1.17	.84	.76
25	1.17	.85	.80
26	1.18	.85	.80
27	1.19	.85	.80
28	1.20	.85	.80
29	1.21	.86	.81
30	1.22	.86	.81

Table 7.—Log-quality index for **SOFT MAPLE** by log grade or class and size class

Log diameter inside bark (inches)	Quality index		
	Log grade No. 1	Log grade No. 2	Log grade No. 3
8	. . .	. . .	0.46
9	. . .	. . .	.48
10	. . .	0.71	.51
11	. . .	.72	.53
12	. . .	.74	.56
13	0.91	.76	.59
14	.94	.78	.62
15	.96	.80	.66
16	.98	.83	.69
17	.99	.85	.73
18	1.01	.88	.76
19	1.02	.90	.79
20	1.04	.93	.82
21	1.05	.95	.85
22	1.06	.97	.88
23	1.07	.99	.91

Table 8.—Log-quality index for **WHITE OAK** by log grade or class and size class

Log diameter inside bark (inches)	Quality index		
	Log grade No. 1	Log grade No. 2	Log grade No. 3
8	. . .	. . .	0.50
9	. . .	. . .	.52
10	. . .	0.69	.53
11	. . .	.71	.55
12	. . .	.74	.56
13	1.01	.75	.57
14	1.07	.77	.59
15	1.11	.79	.60
16	1.15	.80	.62
17	1.19	.83	.64
18	1.22	.84	.66
19	1.24	.86	.69
20	1.25	.87	.71
21	1.27	.89	.74
22	1.29	.91	.77
23	1.32	.93	.80
24	1.35	.95	.83
25	1.39	.97	.88

Table 9.—Log-quality index for **YELLOW-POPLAR** by log grade or class and size class

Log diameter inside bark (inches)	Quality index		
	Log grade No. 1	Log grade No. 2	Log grade No. 3
8	. . .	. . .	0.51
9	. . .	. . .	.52
10	. . .	0.73	.54
11	. . .	.73	.55
12	. . .	.74	.57
13	0.88	.74	.59
14	.90	.75	.60
15	.92	.76	.62
16	.93	.78	.63
17	.95	.78	.65
18	.97	.79	.66
19	.98	.80	.67
20	.99	.81	.68
21	1.00	.81	.69
22	1.01	.82	.70
23	1.02	.83	. . .
24	1.03	.83	. . .
25	1.04	.84	. . .
26	1.05	.85	. . .
27	1.06	.85	. . .
28	1.06	.86	. . .
29	1.06	.87	. . .
30	1.07	.87	. . .

Table 10.—Log-quality index for **WHITE ASH** by log grade or class and size class [1]

Log diameter inside bark (inches)	Quality index		
	Log grade No. 1	Log grade No. 2	Log grade No. 3
8	. . .	. . .	0.57
9	. . .	. . .	.59
10	. . .	0.82	.61
11	. . .	.84	.63
12	1.10	.87	.66
13	1.12	.90	.70
14	1.15	.93	.74
15	1.17	.95	.78
16	1.19	.98	.82
17	1.21	1.00	.86
18	1.24	1.03	.90
19	1.25	1.06	.94
20	1.27	1.08	.97
21	1.29	1.11	. . .
22	1.31	1.13	. .
23	1.33	1.16	. . .
24	1.35	1.18	. . .

[1] Data in tables 10-16 were derived by hand-curving lumber grade yield data from USDA Forest Serv. Res. Paper FPL-63 and 1964-68 lumber prices from *The Commercial Bulletin, Appalachian Area.*

Table 11.—Log-quality index for **BEECH** by log grade or class and size class

Log diameter inside bark (inches)	Quality index		
	Log grade No. 1	Log grade No. 2	Log grade No. 3
8	. . .	. . .	0.49
9	. . .	. . .	.50
10	. . .	0.64	.51
11	. . .	.65	.52
12	. . .	.67	.53
13	0.82	.68	.54
14	.84	.70	.56
15	.87	.73	.58
16	.88	.75	.59
17	.89	.75	.61
18	.90	.77	.63
19	.90	.78	.65
20	.90	.79	.68
21	.91	.80	.70
22	.91	.80	.73
23	.92	.81	.75
24	.92	.82	.79
25	.93	.82	. . .

Table 12.—Log-quality index for **CHERRY** by log grade or class and size class

Log diameter inside bark (inches)	Quality index		
	Log grade No. 1	Log grade No. 2	Log grade No. 3
8	. . .	. . .	0.40
9	. . .	. . .	.46
10	. . .	0.74	.51
11	. . .	.76	.54
12	. . .	.79	.58
13	1.07	.82	.62
14	1.08	.85	.66
15	1.08	.88	.72
16	1.09	.91	.77
17	1.10	.93	.81
18	1.12	.95	.84
19	1.13	.97	.87
20	1.15	.99	.88
21	1.16	1.02	.89
22	1.19	1.04	.90
23	1.21	1.07	. . .
24	1.24	1.09	. .
25	1.26	1.12	.

Table 13.—Log-quality index for **HARD MAPLE** by log grade or class and size class

Log diameter inside bark (inches)	Quality index		
	Log grade No. 1	Log grade No. 2	Log grade No. 3
10	. . .	0.64	0.47
11	. . .	.66	.47
12	. . .	.67	.47
13	0.98	.69	.47
14	.99	.72	.47
15	.99	.74	.48
16	1.00	.76	.48
17	1.01	.78	.49
18	1.01	.80	.49
19	1.02	.82	.50
20	1.04	.84	.52
21	1.06	.86	.54
22	1.08	.88	.56
23	1.09	.91	.58
24	1.12	.93	. . .
25	1.14	.96	. . .
26	1.15	.98	. .

Table 14.—Log-quality index for **RED OAK** by log grade or class and size class

Log diameter inside bark (inches)	Quality index		
	Log grade No. 1	Log grade No. 2	Log grade No. 3
8	. . .	. . .	0.52
9	. . .	. . .	.53
10	. . .	0.76	.53
11	. . .	.77	.53
12	. . .	.77	.54
13	1.00	.78	.54
14	1.08	.80	.54
15	1.11	.81	.54
16	1.13	.82	.55
17	1.14	.82	.56
18	1.15	.82	.57
19	1.15	.82	.59
20	1.15	.82	.62
21	1.15	.82	.64
22	1.15	.82	.67
23	1.15	.83	.71
24	1.15	.83	.75
25	1.16	. . .	.79
26	1.17	. . .	. . .
27	1.17	. . .	. . .
28	1.19	. . .	. . .
29	1.20	. . .	. . .
30	1.21	. . .	. . .

Table 15.—Log-quality index for **WHITE OAK** by log grade or class and size class

Log diameter inside bark (inches)	Quality index		
	Log grade No. 1	Log grade No. 2	Log grade No. 3
8	. . .	. . .	0.49
9	. . .	. . .	.50
10	. . .	0.68	.51
11	. . .	.70	.53
12	. . .	.72	.54
13	1.00	.73	.56
14	1.05	.75	.57
15	1.10	.77	.58
16	1.14	.79	.60
17	1.18	.81	.62
18	1.20	.83	.65
19	1.22	.84	.67
20	1.23	.86	.70
21	1.25	.88	.73
22	1.28	.90	.76
23	1.31	.92	.78
24	1.34	.94	.82
25	1.38	.96	.85
26	1.41	.98	.87
27	1.44	1.01	. . .
28	1.47	1.05	. .

Table 16.—Log-quality index for **YELLOW-POPLAR** by log grade or class and size class

Log diameter inside bark (inches)	Quality index		
	Log grade No. 1	Log grade No. 2	Log grade No. 3
8	. . .	. . .	0.51
9	. . .	. . .	.52
10	. . .	0.73	.54
11	. . .	.73	.55
12	. . .	.74	.57
13	0.88	.74	.59
14	.90	.75	.60
15	.92	.76	.62
16	.93	.77	.63
17	.95	.78	.65
18	.96	.79	.66
19	.98	.80	.67
20	.99	.80	. . .
21	1.00	.81	. . .
22	1.01	.82	. . .
23	1.02	.83	. . .
24	1.03	.83	. . .
25	1.04	.84	. . .
26	1.05	.84	. . .
27	1.05	.85	. . .
28	1.06	.86	. . .
29	1.06	.87	. . .
30	1.06	.88	. . .

Table 17.—Log-quality index for **ASH** by log-grade or class and size class [1]

Log diameter inside bark (inches)	Quality index		
	Log grade No. 1	Log grade No. 2	Log grade No. 3
8	. . .	. . .	0.55
9	. . .	. . .	.56
10	. . .	0.78	.58
11	. . .	.81	.60
12	1.05	.83	.63
13	1.07	.86	.66
14	1.10	.88	.70
15	1.12	.91	.74
16	1.14	.94	.78
17	1.16	.96	.82
18	1.18	.99	.85
19	1.20	1.02	.89
20	1.21	1.04	.93
21	1.23	1.06	.97
22	1.25	1.08	1.00
23	1.27	1.10	1.03
24	1.28	1.12	1.06

[1] Data in tables 17-22 were derived by hand-curving lumber grade yield data from USDA Forest Serv. Res. Paper FPL-63 and 1964-68 lumber prices from *The Commercial Bulletin, Northeastern Area.*

Table 18.—Log-quality index for **BEECH** by log grade or class and size class

Log diameter inside bark (inches)	Quality index		
	Log grade No. 1	Log grade No. 2	Log grade No. 3
8	. . .	. . .	0.50
9	. . .	. . .	.51
10	. . .	0.65	.52
11	. . .	.67	.53
12	. . .	.68	.54
13	0.83	.69	.56
14	.87	.72	.58
15	.89	.74	.59
16	.90	.75	.61
17	.92	.77	.63
18	.93	.78	.65
19	.93	.79	.67
20	.93	.80	.69
21	.95	.81	.71
22	.95	.82	.73
23	.95	.83	.75
24	.95	.83	.77
25	.96	.84	.79

Table 19.—Log-quality index for **BIRCH** by log grade or class and size class

Log diameter inside bark (inches)	Quality index		
	Log grade No. 1	Log grade No. 2	Log grade No. 3
8	. . .	. . .	0.46
9	. . .	. . .	.46
10	. . .	0.66	.46
11	.	.68	.46
12	. . .	.70	.46
13	0.95	.72	.46
14	.98	.74	.46
15	1.01	.76	.47
16	1.05	.78	.47
17	1.12	.81	.48
18	1.17	.83	.49
19	1.22	.85	. .
20	1.27	.87	. .
21	1.30	.90	. . .
22	1.34	.93	. . .
23	1.37	.95	. . .
24	1.38	.98	. . .

Table 20.—Log-quality index for **HARD MAPLE** by log grade or class and size class

Log diameter inside bark (inches)	Quality index		
	Log grade No. 1	Log grade No. 2	Log grade No. 3
8	. . .	. . .	0.57
9	. . .	. . .	.57
10	. . .	0.72	.57
11	. .	.74	.58
12	. . .	.75	.58
13	1.04	.77	.58
14	1.05	.79	.59
15	1.05	.81	.59
16	1.06	.83	.60
17	1.07	.85	.61
18	1.07	.87	.62
19	1.08	.89	.64
20	1.10	.90	.66
21	1.12	.92	.68
22	1.13	.95	.70
23	1.15	.97	.72
24	1.17	.99	.74
25	1.20	1.01	.76
26	1.21	1.03	.78

Table 21.—Log-quality index for **SOFT MAPLE** by log grade or class and size class

Log diameter inside bark (inches)	Quality index		
	Log grade No. 1	Log grade No. 2	Log grade No. 3
8	.	. . .	0.48
9	. .	. . .	.50
10	. .	0.72	.52
11		.73	.55
12	.	.75	.57
13	0.93	.77	.61
14	.96	.79	.63
15	.98	.81	.63
16	1.00	.84	.69
17	1.01	.86	.73
18	1.03	.89	.77
19	1.04	.91	.80
20	1.06	.94	.83
21	1.07	.97	.86
22	1.09	1.00	.89
23	1.10	1.03	.

Table 22.—Log-quality index for **OAK** by log grade or class and size class

Log diameter inside bark (inches)	Quality index		
	Log grade No. 1	Log grade No. 2	Log grade No. 3
8	. . .	. . .	0.65
9	. . .	. . .	.66
10	. . .	0.83	.66
11	. .	.84	.66
12	. . .	.84	.67
13	1.02	.85	.67
14	1.08	.86	.67
15	1.10	.87	.67
16	1.12	.88	.67
17	1.13	.88	.68
18	1.14	.88	.69
19	1.14	.88	.70
20	1.14	.89	.72
21	1.14	.89	.75
22	1.14	.89	.77
23	1.14	.89	.80
24	1.14	.89	.83
25	1.15	.90	.86
26	1.15	.90	. . .
27	1.16	.90	.
28	1.17	.91	. .
29	1.18	.91	. . .
30	1.19	.91	. .

THE FOREST SERVICE of the U. S. Department of Agriculture is dedicated to the principle of multiple use management of the Nation's forest resources for sustained yields of wood, water, forage, wildlife, and recreation. Through forestry research, cooperation with the States and private forest owners, and management of the National Forests and National Grasslands, it strives — as directed by Congress — to provide increasingly greater service to a growing Nation.

for estimating skidder

by Cleveland J. Biller

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NORTHEASTERN FOREST EXPERIMENT STATION, UPPER DARBY, PA.
FOREST SERVICE, U.S. DEPARTMENT OF AGRICULTURE
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TABLES
for estimating skidder
TIRE WEAN

■

THIS BOOK OF TABLES was prepared to help the logging operator estimate how much a particular logging job will wear the tires on his rubber-wheeled skidders. This is an important element in the cost of a logging operation. The logging operator can translate these estimates of tire wear into a production cost.

The wheeled skidder—an articulated, four-wheel drive, rubber-tired, diesel-powered vehicle used to transport logs from the stump to the landing—has become almost standard equipment on logging jobs in the Northeast. The large rubber tires, some of which cost more than $800 each, take severe punishment in rough forest terrain.

Because the purchase and maintenance cost for tires is so great a part of the total production cost, the logger wants to know how much of the cost of logging can be attributed to tires. The measure of cost is how much his tires will wear during a logging operation.

The tables in this book were based on data from a tire-wear study made in Appalachia by the engineering staff of the USDA Forest Service's Forestry Sciences Laboratory at Morgantown, West Virginia.

HOW THE TABLES WERE PREPARED

The most important factor considered in this study was the amount of tread that is worn off in a known unit of operating time. (A new tire has approximately 1.5 inches of tread.) Seventy-six tires were measured periodically at an average of 60 working days between measurements, equivalent to 3 months' wear. The value for slope used in the tables was the average slope of all the logging operations, 28 percent. The data were collected in the Appalachian area, and will apply only to this area (fig. 1).

A small metal ruler and a vernier caliper with a depth gage were used to measure the depth of tread (fig. 2). The point of measurement was taken at the center of the tire between two lugs. When it was obvious that large chunks of tread had been torn away, this spot was not measured. Three measurements were taken, spaced as evenly as possible around the tire. The three measurements for each tire were averaged.

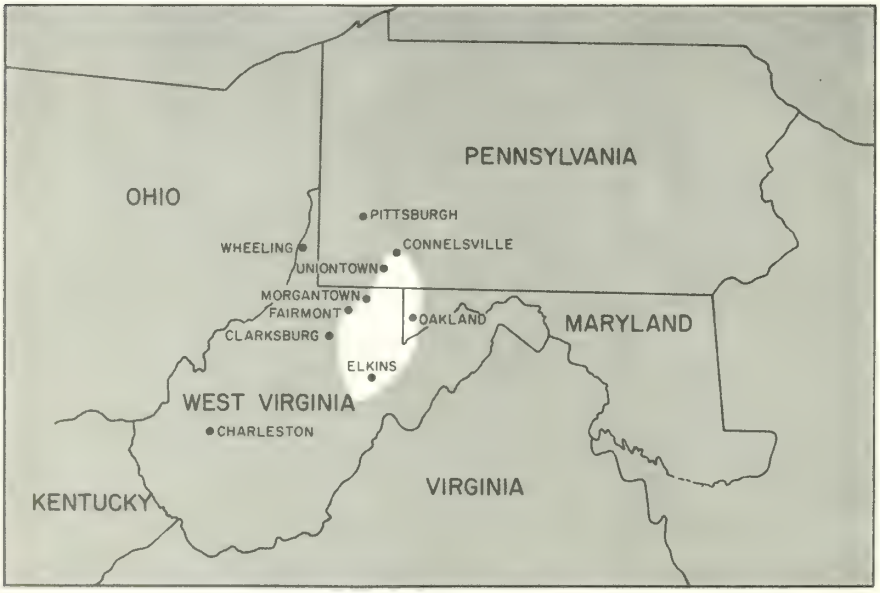

Figure 1.—The Appalachia area where the data were collected.

Figure 2.—The method used to measure depth of tread.

Factors considered in the study were: type and texture of soil, weight of skidder, horsepower of skidder, board feet skidded per day, degrees of skidroad rockiness, total hours worked, tire position (front or rear), slope of skidroad, number of tire repairs, tire brand, size, number of plies, and type of construction.

The type and texture of soil was constant in this study. The soil classification was a mixed soil in which sand was the predominant factor.

The rockiness of the skidroads was treated as follows. First, a representative 50-foot section of skidroad was chosen on each logging operation. The visible cross-section of each rock was measured and recorded. The skidroad was then classified according to rock size.

Two road classifications were used in this study: small rock and large rock. The small rock classification was applied to a

representative section of skidroad that had rocks in visible cross-sections of less than 15 inches (fig. 3). The large rock classification was applied to a representative section of skidroad that had rocks in visible cross-sections larger than 15 inches (fig. 4).

Computer analyses were applied to the data. From these analyses four prediction equations were determined for each road class. We had an estimate of tire wear for each of the four tire locations; right front, left front, right rear, and left rear. From these estimates we chose the greatest wear on the two front tires and the greatest wear on the two rear tires.

The tables were prepared for several makes and sizes of skidders, and for the two classes of skidroad, making a total of 11 tables. The make of machine is mentioned for information only, and mention of the make should not be taken as an endorsement by the Forest Service or the Department of Agriculture.

Figure 3.—A skidroad classed as "small rock".

Figure 4.—A skidroad classed as "large rock".

How to Use the Tables

- First decide which skidroad rockiness classification fits your logging area.
- Locate the table for the make and model of your skidder, and for your skidroad classification. These two items are shown at the top of the table.
- Locate in the table the general areas that fit your tire diameter and width.
- In column 1, locate the line for your production in thousand board feet.
- Read across this line to the right to find the inches of wear predicted for the front and rear tires.

Try an example. Your skidder is a John Deere 440, and the

skidroad classification for your operation is large rocks. Find the table labeled for these (table 5).

Your tire diameter is 30 inches; tire width is 16.9 inches. Read down the table until you find the block of data for your tire diameter and your tire width. In column 1 you find a series of daily production rates. Locate your daily production rate. If your daily production rate is 14 thousand board feet, this is the line you want.

Read across this line to the right and you find the amount of tire wear, in inches, for the front and rear tires: for front tires 0.33 inch, for rear tires 0.24 inch.

This is how much wear you can expect on each wheel of your skidder for the logging operation you plan. This information is for working the machine for 60 days. From this you can estimate how much in tire wear this job is going to cost. Example: if an operation will take 120 working days to complete, your tire wear for those 120 working days will be approximately twice the 60-day value or 0.66 inches of wear on each front tire and 0.48 inches of wear on each rear tire.

■

Table 1.

FRANKLIN 103 — SMALL ROCKS

(MACHINE DAYS: 60)

Daily production rate (1,000 board feet)	Predicted tire wear (in inches)	
	Front	Rear
DIAMETER 26.0 INCHES; WIDTH 16.9 INCHES		
4	0.0+	0.0+
6	.04	.0+
8	.08	.03
10	.12	.07
12	.15	.11
14	.19	.15
16	.24	.19
DIAMETER 26.0 INCHES; WIDTH 18.4 INCHES		
4	0.04	0.04
6	.08	.07
8	.12	.09
10	.16	.13
12	.20	.16
14	.25	.20
16	.30	.24

Table 2.

FRANKIN 130-B — SMALL ROCKS

(MACHINE DAYS: 60)

Daily production rate (1,000 board feet)	Predicted tire wear (in inches)	
	Front	Rear
DIAMETER 26.0 INCHES; WIDTH 18.4 INCHES		
4	0.0+	0.0+
6	.04	.03
8	.08	.07
10	.13	.11
12	.18	.14
14	.23	.18
16	.28	.22

Table 3.

FRANKLIN 160-B — SMALL ROCKS

(MACHINE DAYS: 60)

Daily production rate (1,000 board feet)	Predicted tire wear (in inches)	
	Front	Rear
DIAMETER 26.0 INCHES; WIDTH 23.1 INCHES		
4	0.19	0.26
6	.24	.29
8	.29	.32
10	.34	.34
12	.40	.37
14	.45	.40
16	.50	.43

Table 4.

JOHN DEERE 440 — SMALL ROCKS

(MACHINE DAYS: 60)

Daily production rate (1,000 board feet)	Predicted tire wear (in inches)	
	Front	Rear
DIAMETER 30.0 INCHES; WIDTH 16.9 INCHES		
4	0.0+	0.0+
6	.0+	.0+
8	.04	.02
10	.09	.05
12	.14	.09
14	.20	.13
16	.25	.17

Table 5.

JOHN DEERE 440 — LARGE ROCKS

(MACHINE DAYS: 60)

Daily production rate (1,000 board feet)	Predicted tire wear (in inches)	
	Front	Rear
DIAMETER 26.0 INCHES; WIDTH 18.4 INCHES		
4	0.05	0.06
6	.08	.09
8	.14	.12
10	.19	.15
12	.24	.19
14	.29	.23
16	.34	.26
DIAMETER 30.0 INCHES; WIDTH 16.9 INCHES		
4	0.10	0.09
6	.14	.11
8	.18	.14
10	.22	.17
12	.28	.21
14	.33	.24
16	.38	.28

Table 6.

JOHN DEERE 440A — SMALL ROCKS

(MACHINE DAYS: 60)

Daily production rate (1,000 board feet)	Predicted tire wear (in inches)	
	Front	Rear
DIAMETER 26.0 INCHES; WIDTH 18.4 INCHES		
4	0.0+	0.0+
6	.0+	.0+
8	.03	.02
10	.08	.06
12	.13	.10
14	.19	.14
16	.24	.18
DIAMETER 30.0 INCHES; WIDTH 16.9 INCHES		
4	0.0+	0.0+
6	.01	.01
8	.07	.04
10	.12	.08
12	.17	.12
14	.22	.16
16	.27	.19

Table 7.

PETTIBONE MASTER 8 — SMALL ROCKS

(MACHINE DAYS: 60)

Daily production rate (1,000 board feet)	Predicted tire wear (in inches)	
	Front	Rear
DIAMETER 26.0 INCHES; WIDTH 18.4 INCHES		
4	0.0+	0.0+
6	.01	.01
8	.05	.05
10	.11	.09
12	.16	.12
14	.21	.16
16	.26	.20

Table 8.

PETTIBONE MASTER 8 — LARGE ROCKS

(MACHINE DAYS: 60)

Daily production rate (1,000 board feet)	Predicted tire wear (in inches)	
	Front	Rear
DIAMETER 26.0 INCHES; WIDTH 18.4 INCHES		
4	0.15	0.16
6	.18	.19
8	.22	.22
10	.26	.24
12	.30	.27
14	.34	.30
16	.39	.33

Table 9.

TIMBERJACK 225 SMALL ROCKS

(MACHINE DAYS: 60)

Daily production rate (1,000 board feet)	Predicted tire wear (in inches)	
	Front	Rear
DIAMETER 26.0 INCHES; WIDTH 18.4 INCHES		
4	0.01	0.01
6	.05	.04
8	.09	.07
10	.13	.11
12	.18	.15
14	.24	.19
16	.29	.23
DIAMETER 30.0 INCHES; WIDTH 16.9 INCHES		
4	0.07	0.03
6	.11	.06
8	.14	.09
10	.18	.13
12	.22	.17
14	.27	.21
16	.32	.24

Table 10.

TIMBERJACK 225 LARGE ROCKS

(MACHINE DAYS: 60)

Daily production rate (1,000 board feet)	Predicted tire wear (in inches)	
	Front	Rear
DIAMETER 26.0 INCHES; WIDTH 18.4 INCHES		
4	0.20	0.21
6	.24	.24
8	.28	.27
10	.31	.30
12	.35	.33
14	.39	.35
16	.43	.38
DIAMETER 30.0 INCHES; WIDTH 16.9 INCHES		
4	0.25	0.24
6	.29	.27
8	.33	.30
10	.37	.32
12	.41	.35
14	.44	.38
16	.48	.41

Table 11.

C-7 TREE FARMER — LARGE ROCKS

(MACHINE DAYS: 60)

Daily production rate (1,000 board feet)	Predicted tire wear (in inches)	
	Front	Rear
DIAMETER 30.0 INCHES; WIDTH 18.4 INCHES		
4	0.30	0.31
6	.34	.34
8	.38	.37
10	.41	.39
12	.45	.42
14	.49	.45
16	.53	.48

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by Johnson Parker

Effects of Defoliation and Drought on ROOT FOOD RESERVES in SUGAR MAPLE Seedlings

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1970

NORTHEASTERN FOREST EXPERIMENT STATION, UPPER DARBY, PA.
FOREST SERVICE, U.S. DEPARTMENT OF AGRICULTURE
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THE PROBLEM

THE ARTIFICIAL defoliation of sugar maple *(Acer saccharum* Marsh.) can cause a marked decline in root food reserves, especially starch, and an increase in the levels of the reducing sugars, fructose and glucose. Defoliation can also bring on the dieback-decline syndrome in sugar maples *(Parker and Houston 1968)*.

Because drought, too, can bring on dieback symptoms, the question arose whether drought (or a combination of drought and defoliation) has the same effect as defoliation on root food reserves and reducing sugars.

Two experiments designed to examine this question were conducted in 1968-69. In one, the effects of both drought and defoliation were examined; in the second, defoliation was eliminated as a variable. This paper is a report on those experiments.

Root food reserves are defined as the material, consisting of proteins, lipids, and carbohydrates (including starch), which is extracted with methanolic trichloroacetic acid. Certain cell-wall constituents removed by other and older methods are not included in this definition *(Priestley 1965)*.

THE EXPERIMENTS

Methods

Experiment I.—Ninety forest-grown sugar maple seedlings, about 6 years old and 18 inches tall, were dug in May 1967 and planted in 8-inch plastic pots containing forest topsoil. The seedlings were grown under partial shade and were watered frequently during the summer of 1967. In autumn they were heeled in and mulched with pine needles.

In mid-June 1968 the soil in all pots was brought to field capacity by soaking from above. The pots were covered with two layers of black plastic, which were slit to fit around the stems and were bound to the pots with string. A masonite cover, slotted

to fit the stem, was placed over the plastic on each pot, and the slot was covered with masking tape.

The 90 seedlings were divided into 3 groups of 30 each (table 1). Seedlings in the first group were not defoliated; those in the second group were defoliated once, on 1 July 1968; and those in the third group were defoliated twice, once on 1 July and again on 5 August.

Three watering regimes were used for all groups: (1) 10 seedlings in each group were watered once a week (watered), (2) 10 were watered once every 2 weeks (intermittently watered), and (3) 10 were not watered (unwatered). The seedlings that were watered and not defoliated served as the control group.

The pots, with contents and covers, were weighed after thorough watering to determine their initial total weight. They were then weighed every week, partly to determine the levels to which water should be added in the watered and intermittently watered pots, and partly to determine the point—presumed to be the wilting point—at which weight loss ceased in the unwatered plants.

The pots were arranged randomly on shelves in a screened enclosure that was covered with a layer of clear polyethylene.

All seedlings were harvested on 6 September, 1968; this was before leaf-fall. Roots were removed and kept frozen at —15°C. for 3 months before they were analyzed.

Food reserves (FR) were determined in the thicker part of the root, 7 to 10 cm. below the root collar. A modification of Priestley's *(1965)* analytical procedure was used.

Table 1.—*Food reserves in sugar maple roots, as percent of dry weight*

Treatment	Non-defoliated	Once defoliated	Twice defoliated	Average
Watered	30.1	29.6	23.5*	27.6
Intermittently watered	27.0	30.5	26.4	28.0
Unwatered	28.7	31.6	25.1	28.4
Average	28.6	30.6	25.0*	—

*Significantly different from controls (nondefoliated, watered) at probability of 0.90.

Enough 3-mm.-thick disks were cut from the root to fill a 12-ml. weighing bottle. The bottle containing root disks was capped and weighed to determine fresh weight, was oven-dried for 48 hours at 105°C., and was reweighed to 0.001 g. to determine pre-extraction weight.

To perform an extraction, the contents of a weighing bottle were placed in a 250-ml. flask that was attached through a ground glass joint to a water-cooled condenser. The contents were then refluxed for 2 hours in 150 ml. of 5 percent trichloroacetic acid (TCA) solution in 35 percent methanol. The liquid portion was suction-filtered off and discarded; the root pieces were transferred to the thimble of a Soxhlet apparatus and extracted with 170 ml. of once-distilled tap water for 8 hours.

The sample was dried in the thimble at 70°C. for 1 hour, placed in a weighing bottle, and oven-dried at 105°C. for 48 hours. All samples were cooled 20 minutes in a desiccator before capping and weighing.

Original (pre-examination) dry weight minus dry weight after extraction was used as a measure of food reserves. Weight loss was expressed as a percentage of original dry weight.

Starch was estimated from microscopically examined hand-cut cross-sections of roots stained with I_2-KI. The amount of starch present was expressed as the percentage of the total cross-sectioned area occupied by starch-filled cells.

Experiment II.—In the second experiment, three groups of 17 seedlings each were dug in the autumn of 1968. None of these seedlings was defoliated. The three watering regimes used in the summer of 1969 were the same used in the first experiment.

The seedlings, in uncovered pots, were placed on boards resting on the ground and were protected from rainfall by a polyethylene canopy about 10 feet above them and open on the sides.

On 16 July, 1969 the roots of eight seedlings, selected randomly from each of the three groups, were dug up, cut off, frozen, and analyzed for sugars by means of paper chromatography *(Parker 1962)*. Starch was determined as above.

The remaining seedlings (nine per treatment) were harvested on 19 August and were analyzed for sugars and starch.

Results

Experiment I.—Food reserves in the roots of the seedlings that were watered and defoliated twice averaged 23.5 percent of the total root dry weight (table 1). This was significantly lower (at a probability of 0.90) than the food reserves of the control group (seedlings watered once a week and not defoliated), which averaged 30.1 percent of the total root dry weight. However, the food reserves of the seedlings in the group that was watered and defoliated once averaged 29.6 percent—not significantly different from the food reserves of the control group.

When all the watering regimes were pooled, the food reserves of all defoliated seedlings were significantly lower than those of the controls.

Seven of the 10 nondefoliated and unwatered seedlings dried to the wilting point. The three that did not were omitted from analysis. The food reserves of the seven unwatered and wilted seedlings were not significantly different from those of the controls, although the average food reserves were lower on the average than those of the controls (table 1). Two control seedlings were omitted because the soil dried out during the experiment. Another control seedling died and was omitted.

The soil of most of the defoliated and unwatered seedlings did not dry out enough to reach the wilting point, apparently because of the reduced transpiration in the defoliated seedlings.

Table 2.—*Estimates of starch in root sections as a percentage of the cross-section area occupied by cells containing starch (experiment I)*[1]

Treatment	Non-defoliated	Once defoliated	Twice defoliated	Average
Watered	90	30	5	42
Intermittently watered	75	55	15	48
Unwatered	65	40	20	42
Average	77	42	13	—

[1]Significances not computed because estimates were based on visual microscopic observations.

No significant differences in food reserves were found among defoliated seedlings in the different watering regimes (table 1).

Starch averaged 13 percent in seedlings defoliated twice, 42 percent in seedlings defoliated once, and 77 percent in seedlings that were not defoliated (table 2). Starch levels also were different between nondefoliated seedlings that were watered (90 percent), unwatered (65 percent), and intermittently watered (75 percent).

Experiment II.—There were significantly (0.95 probability) greater amounts of fructose and glucose in the roots of unwatered seedlings than in the roots of watered seedlings in both the July and August harvests (fig. 1). Although sucrose was greater in

Figure 1.—Percent fructose, glucose, and sucrose, based on root dry weight, for the three watering regimes: water (WAT.), intermittently watered (INT.), and unwatered (DRY) from mid-June to time of harvest (16 July or 19 August). Significant differences in reducing sugars were found between watered and both intermittently watered and unwatered seedlings in July, and between unwatered and both intermittently watered and watered seedlings in August.

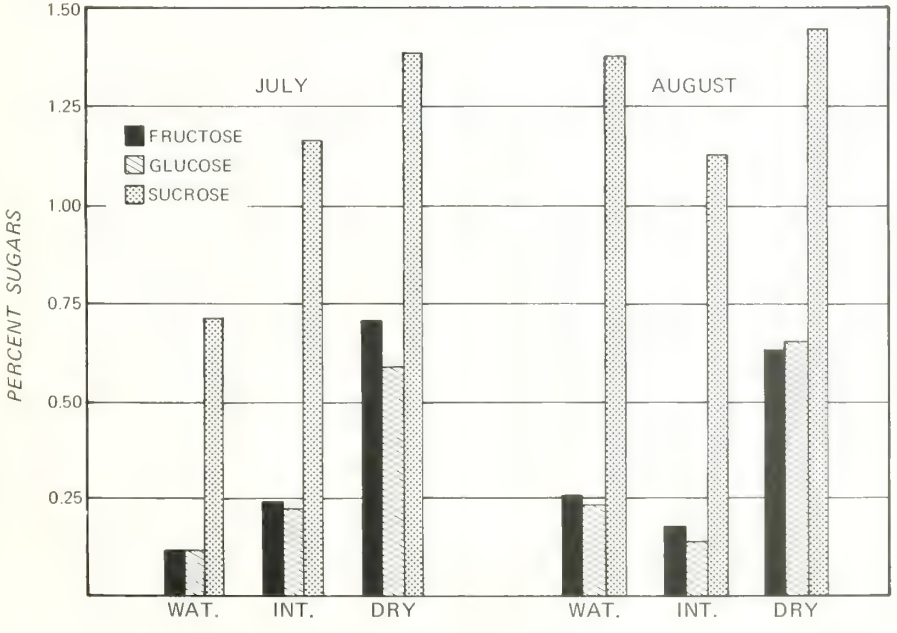

Table 3.—*Estimates of starch in root sections as a percentage of cross-section area occupied by cells containing starch (experiment II)*[1]

Treatment	July 16	August 19
Watered	90	95
Intermittently watered	95	95
Unwatered	60	25

[1]Significance was not computed because estimates were based on visual microscopic observations.

July in unwatered than in watered seedlings, this difference was not significant at 0.90 probability. Traces of raffinose and stachyose occurred occasionally in the extracts, but were not estimated quantitatively.

Starch was lower in August in the unwatered seedlings than in the intermittently watered or watered seedlings. Such differences were not so clearcut in July (table 3), indicating a definite decline in starch in the unwatered seedlings between the July and August harvests.

DISCUSSION

The results of the two experiments show that drought and defoliation have similar effects on carbohydrates in sugar maple roots: both treatments lower starch levels and raise reducing sugar levels. Sucrose may also increase, but the increase was not statistically significant in our results.

Although defoliation reduces total food reserves, drought does not seem to affect them very much. Perhaps the food reserves in the unwatered plants were maintained longer because drought does not abruptly curtail the photosynthetic capacity of the plant, but defoliation does. There also might have been no net change in the food reserves in the unwatered seedlings because carbohydrates not present as starch were present as sugar. Thus the starch decline in unwatered seedlings is not simply a case of root starvation, but most likely is the result of a carbohydrate shift from starch to soluble sugars.

The results of a number of earlier studies are similar to those presented here. Levitt *(1956)* concluded from his review, which dealt mostly with herbaceous plants, that starch was usually converted to sugar during drought unless injury occurred. This conversion is often associated with increased activity of amylases *(Vaadia et al. 1961)*. According to Eaton and Ergle *(1948)*, starch was converted to hexose sugars in the tops of cotton plants during a drought, and sucrose and starch as well as hexose sugars increased in the roots. In prolonged drought, carbohydrate percentage in the whole plant doubled.

Henrici *(cited by Stocker 1960)* found that levels of reducing sugars in lucern (alfalfa) leaves rose until the leaves had completely wilted; then the level declined. Starch underwent a general decline that began early in the experiment. The decline of reducing sugars might be explained by respiratory loss *(Vaadia et al. 1961)*. In loblolly pine (*Pinus taeda* L.) subjected to drought, there was a marked increase in reducing sugars, nonreducing sugars, and total carbohydrates, and a decrease in starch *(Hodges and Lorio 1969)*. But is was felt that the sugar increases were primarily the result of decreased growth, not of starch hydrolysis.

The starch and sugar changes reported in our study probably occur in many other eastern deciduous tree species, besides sugar maple, when they are subjected to drought. A number of chestnut oak *(Quercus prinus* L.) seedlings were included in experiment II, although the data are not presented. In July, no clear differences were found between the levels of reducing sugars in unwatered and control chestnut oak seedlings, but in August the levels of reducing sugars in unwatered seedlings showed a marked increase. Sucrose concentration was not affected by the various watering regimes. By August, starch was clearly lower in the roots of unwatered seedlings than in those of controls.

This increase in reducing sugars after stress brought on by defoliation or drought may help to explain why certain microorganisims capable of metabolizing specific sugars may attack such stressed trees. There is evidence that such microorganisms attack trees affected by defoliators more often than they do healthy trees

(Houston and Kuntz 1964), and it seems clear that drought also can be a contributing factor to the dieback-decline syndrome.

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THE FOREST SERVICE of the U. S. Department of Agriculture is dedicated to the principle of multiple use management of the Nation's forest resources for sustained yields of wood, water, forage, wildlife, and recreation. Through forestry research, cooperation with the States and private forest owners, and management of the National Forests and National Grasslands, it strives — as directed by Congress — to provide increasingly greater service to a growing Nation.

Techniques for the WHEELED-SKIDDER Operator

FEB 10

by Robert L. Hartman
and Harry G. Gibson

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THE SKIDDER OPERATOR IS A KEY MAN

HOW MUCH PRODUCTION a logger gets from a logging job may depend heavily on his skidder operators. They are key men on any logging job.

This is one conclusion that forestry engineers at the USDA Forest Service's Forestry Sciences Laboratory at Morgantown, West Virginia, came to after studying the operation of wheeled skidders in mountainous Appalachian terrain. Out of these studies we can suggest ways that new or experienced skidder operators might improve their operating ability and thus increase their production.

This information might also be helpful to logging contractors in training their skidder operators for more efficient production.

BUNCHING LOGS FOR SKIDDING

Winching logs from the felling site to the skidroad is usually the most time-consuming phase of skidding. And this phase offers the skidder operator a good chance for increasing production.

The slope a log is winched over affects the winching time most. But winching time is affected by distance, undergrowth, slash, stumps, rocks, soil conditions, and characteristics of the particular skidder.

To see how winching capacity of particular skidders was affected by field conditions, we tested the winching force developed by three different skidders. Testing conditions such as soil moisture, soil texture, and skidder operator were the same for each skidder and for each test. In the tests, the mainline was anchored to a standing tree with a dynamometer in series with the anchor and the mainline. Data were taken on each skidder only after the operator had gained experience operating that skidder.

The winching force varied between skidders as follows:

Skidder	Skidder weight (lbs.)	Winching force	
		Rated[1] (lbs.)	Maximum[2] (lbs.)
A	11,673	18,000	13,000
B	12,400	22,000	13,000
C	14,320	25,900	14,500

Condition of the soil was probably the most important factor in this decrease in winching force under forest conditions, but other factors may have been the differences in skidder weight, distribution of weight, wheel base, and fairlead design.

We tested winching force at distance from 20 to 80 feet. Winching force was not affected by distance.

Winching force dropped off as the angle between skidder and winch line increased (fig. 1). At an angle of 45 degrees, two of the skidders tested were capable of less than 50 percent of their po-

[1] Rating on the winching specification plate.

[2] This is the maximum force developed under forest conditions. Winching angle and soil conditions permitted a greater winching force than skidder weight.

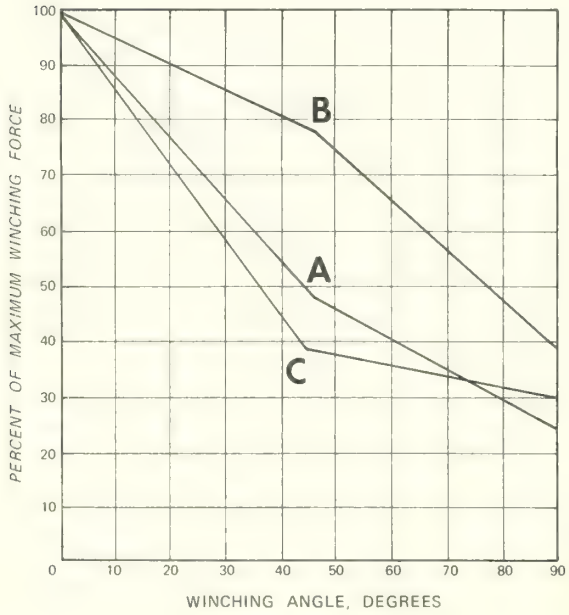


Figure 1. — Percent of maximum forest winching force obtained at different winching angles. (See the tabulation in the text for maximum forest winching forces).

tential winching force relative to winching on a straight line, and the third's force dropped to less than 80 percent. As the winching angle increased to 90 degrees, the winching forces continued to drop. The winching curve for skidder B (fig. 1) indicates that somewhere in the design of this skidder an advantage in stability was gained.

On all skidders, the potential for winching from an extreme angle was poor; therefore, the operator should winch from as straight an angle as possible.

Some wheeled skidder operators in the hardwood areas impact-load the winch mainline to get a large log to start moving. They do this by raising the front of the skidder off the ground with the winch, and then quickly releasing the winch brake until the front of the skidder has gained some downward momentum. Then they re-engage the winch before the front wheels of the skidder hit the ground. This jerks the log into motion.

Impact-loading the mainline is dangerous. If the line breaks, metal fragments and the whipping mainline can be lethal. The loads imposed on the winch, winch mounts, mainline, and other components are high and may damage these components. For a skidder weighing 7 tons, with the front wheels raised 2 feet and then dropped, the force generated would be in the order of 20 to 40 tons!

Engine r.p.m. (revolutions per minute) plays an important role in winching. If the operator cannot see the log, winching should be slow so the operator can detect early when the log has met some obstacle such as a tree or stump. If the engine is turning at a high r.p.m. when an obstacle of this nature is met, the operator may not have time to disengage the winch in time to avoid damage to the machine or cable or to avoid endangering nearby workers.

From our experience with some of the latest skidder models, we recommend that, unless the operator can see the moving log and its path toward the skidder, the engine r.p.m. should be kept under the midpoint of its rated maximum. When the log is visible, the operator can adjust the engine r.p.m. according to existing conditions in the winching path.

Winching from an angle that causes the cable to build up too

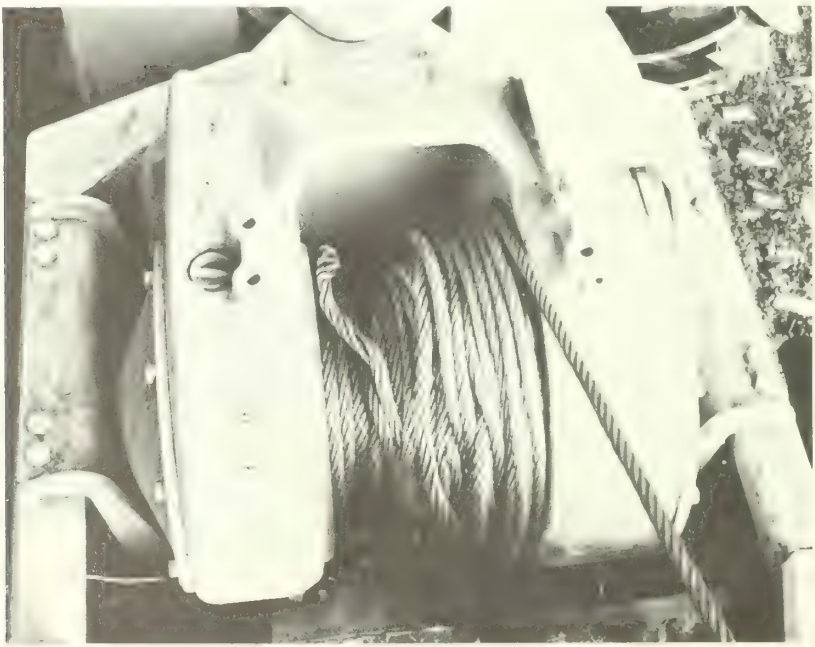
high on one side of the drum can result in permanent damage to the mainline and prevent the mainline from free-wheeling out for the next log (fig. 2). The initial damage shows in a flattened and permanently kinked mainline. The resulting difficulty in pulling the mainline off the drum results in lost time.

The first position selected for winching should be the best one. Moves are time-consuming, especially if the cable has already been pulled out and attached to the log. But if a better position is needed and can be found, it may be best to move the skidder.

The choker setter, by selecting the path of the log through various obstacles, determines to a great degree the effiiciency of the winching operation. As a general rule, the winching path should be as straight as possible and as much in line with the log as possible. If a crooked winching path is selected, longer logs can easily become lodged between trees and stumps (fig. 3).

A low obstacle, such as a rock or stump, can be overcome when

Figure 2.—This cable is wound too much to one side of the winch drum. Note the damage to the cable.



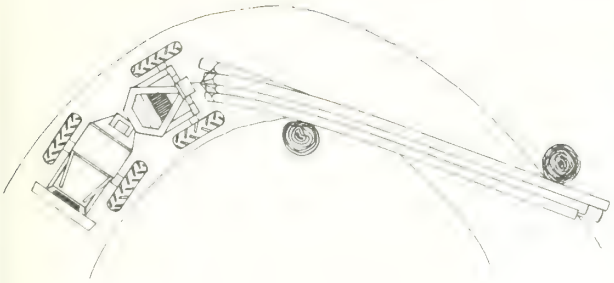


Figure 3.—Problems arise when trying to winch logs out of tight spots at too sharp an angle or when turning too sharply while skidding. The load may lodge against trees, stumps, rocks, or road banks.

it is near the skidder by lifting the front of the log high enough to allow the log to slide over it.

When a large log has been felled in a difficult position because of angle or obstructions, it is best to get the skidder as near the log as possible for winching. This will permit a better view of the obstructions, and the cable will have a greater upward angle, which will aid in sliding the log over rocks, stumps, or slash.

Sometimes a stump or rock will block the winching path for ordinary log-winching methods. There are three good methods of handling this situation. One is to lift the log by moving the skidder near enough for a high-angle pull. The second is to wrap a turn of cable, in addition to the choking loop, around the log to produce a rolling or twisting motion when the cable is pulled. This aids the log in climbing or rolling over the obstruction. The third is to change the angle of pull by looping the cable around a tree or stump (fig. 4)—but be sure no one is near the cable. If the cable slips over the stump, it can injure someone in its path.

Sometimes large logs are difficult to winch uphill and are too heavy to skid. The operator should not try to winch from a long distance, nor should he try to skid the load by spinning the wheels and jerking the skidder. Getting close to the log and aligning the mainline with the direction of travel of the log will usually allow the log to be moved.

Here are a few guidelines for winching:

- When positioning the skidder for winching, keep the angle of pull as small as possible.

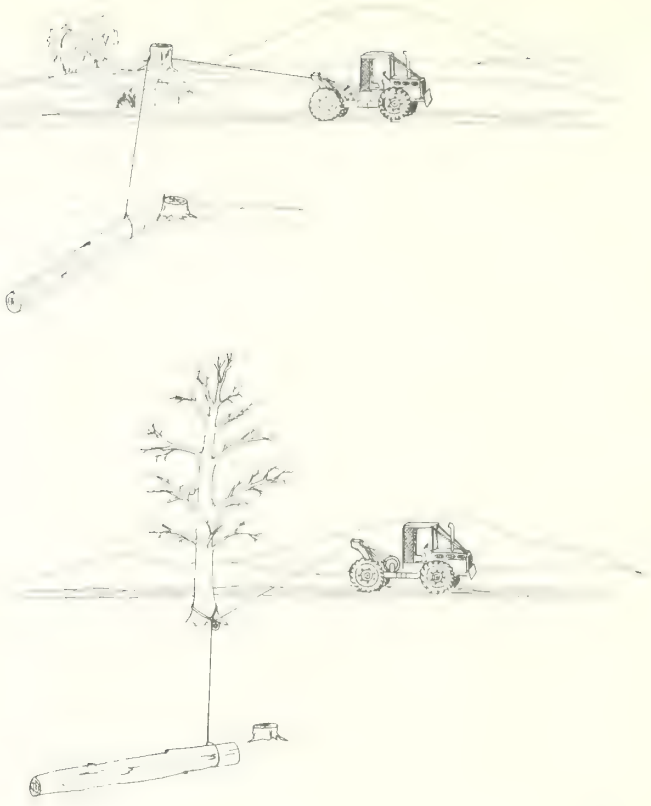


Figure 4.—Two good methods for changing the angle of pull while winching. These are especially valuable in steep terrain. Be sure no one is near the cable. If the cable slips over the stump, it can injure someone in its path.

- Winch slowly at severe angles for better laying of the mainline on the drum.
- Watch the mainline as it is wound onto the winch drum, as this is when the damage usually occurs.
- Operate the hydraulic steering slightly to change the winching angle as the mainline is winding onto the winch drum.
- After the log has been winched a short distance, a smaller winching angle might be attained by repositioning the skidder.
- Do not impact-load the mainline. It is a very dangerous practice.

Load Selection

The operator should recognize the limitations and potentials of the machine at various load levels under the skidding conditions of the particular logging site. He should select the size of load and the particular logs for each skidding cycle accordingly.

The major factors to be considered in selecting the proper load are:

- Slope of the skidroad.
- Turns in the skidroad.
- Length of the skidroad.
- Soil conditions.
- Log size.
- Skidder weight and horsepower.

The load should be selected by the skidder operator, as he is the person most familiar with the skidder and the prevailing skidroad conditions. The operator should recall the size of the load and the gear in which the skidder successfully negotiated a grade, and whether any downshifting was necessary. The grade may be negotiated without downshifting by only slightly reducing the load.

Soil conditions, such as texture and moisture content, affect selection of the load. Loose ground, wet clay, or rocks are conducive to slippage, which results in excessive tire wear and possible tire damage.[3] The operator can best compensate for these soil conditions by decreasing the load size. Many times, only a slight decrease in load is necessary to substantially decrease cycle time and to prevent unnecessary tire wear and damage.

If there are sharp turns in the skidroad, the load should be selected so that there will not be more than one large-diameter log in each load. The large-diameter logs reduce the ability of the skidder to negotiate a sharp turn because they cannot be carried

[3] Biller, Cleveland J. Prediction of skidder tire wear in Appalachia. Presented at ASAE Winter Meeting, 1969, Chicago, Ill. In preparation for publication.

high against the rear of the skidder without interfering with the fenders. Also, the large logs put more weight on the skidder, and more force is required to pivot where the logs attach to the skidder.

There should not be more than one log in each load that is too long to be pulled around a sharp turn without the middle or end of the log dragging against an obstruction (fig. 3). If this occurs frequently, remove the obstruction.

A large load of logs is not necessarily the most economical load. The effect of the load size on the skidding cycle time (the time it takes to make a round trip) must be considered. When a skidder is loaded to its absolute maximum, speed and steering are seriously affected.

A heavy load carried high against the skidder adds to the traction of the rear wheels but does not help the traction of the front wheels. Good front-wheel traction, as well as rear-wheel traction, is desirable for best performance during turning.

A load that is too large may rub against the wheel on the inside of turns. This restricts turning ability, causes tire damage, and, on steep slopes, may upset the skidder.

Reducing the load size will reduce the force necessary to pull the logs, increase traction of the front wheels, reduce physical turning restrictions, and allow more speed while turning, thus allowing the skidder to use its maximum turning ability.

It is a good practice for the skidder operator (or the woods foreman) to periodically check skidding cycle time with a watch. This will give an indication of the effect of overloading or of logs too long for sharp turns.

Overloading puts more strain on the skidder, which leads to more repairs and higher operating costs. The operating costs should not be taken lightly, as they effect the harvesting system much the same as does low production. In fact, breakdowns, tire damage, and cable and choker damage all result in non-productive time, which brings about low production as well as the direct costs of repairs.

Fortunately, the wheeled-skidder operator can control some of the factors that effect production and costs. This is rapidly becoming more important as equipment and repairs are becoming more

expensive. The operator should strive for better utilization of the wheeled skidder through care and maintenance.

SKIDROAD TRAVEL LOADED

After the load has been selected and properly attached to the mainline, the logs are pulled forward and raised to the proper height for skidroad travel. It is easy to raise the forward end of some loads while the skidder is at a standstill. The operator must pay particular attention to the front end of the logs, as they have a tendency to move forward as the lifting begins. Sometimes the logs move forward far enough to catch under the log fenders or the rear of the skidder frame. And unless the operator is alert and disengages the power to the winch, the mainline or chokers may be broken. Because of this, we recommend that the engine be maintained at a low r.p.m. while the logs are being lifted. Otherwise, the momentum built up in the winch by a high engine r.p.m. could allow the winch to cause damage to the wire rope even though the operator did release the power from the engine.

Another technique for lifting the logs is to winch the logs close to the rear of the skidder and then move the skidder forward while the winch is lifting the logs to the desired height. The logs drag on the ground as the machine moves forward, keeping the logs farther back from the log fenders. This is probably the most used of the two techniques, but the operator should use caution while he steers the skidder and watches the winching. Also, this technique pulls the cable more nearly horizontally and may allow a choker to pull off, causing a delay while the log is being re-choked.

The logs should be carried as high as possible. However, two limiting factors are the height of the fairlead and the length of the chokers. The loaded chokers should not be wound onto the winch drum, as the connectors and the underlying layers of cable may be damaged.

If there is a steep side slope to the skidroad, the logs should be carried lower than they would be on a level skidroad. The logs apply more force to the log fenders on the downhill side of the skidder and could cause the skidder to overturn.

Danger of overturning the skidder is greatest when turning on a slope. The two most critical types of turns are traveling downslope and turning left or right and traveling around a slope and turning up.[1] These turns are critical with the skidder either loaded or unloaded. Although turns of this nature should be avoided, sometimes they are necessary.

Momentum can be a major factor in overturning or upsetting a skidder while turning, so the operator should proceed slowly. The forward ends of the logs should be carried at a lower level than usual. If the raised logs are pushing or forcing the skidder to overturn, their effect can be eliminated quickly by releasing the winch brake and dropping them to the ground. After they are released and on the ground, they can be used as an anchor for holding the skidder from overturning. This may require that the skidder be turned to a slightly different angle by manipulating the articulated frame while the logs are being dropped to the ground. These techniques require the skidder operator to become as familiar as possible with his skidder and to remain alert to the different forces acting on it.

If the load must be pulled up a steep slope or through a swampy area, the operator should study the ability of the skidder to carry different-size loads over these problem areas. Before entering the problem area, he should shift the skidder into a gear that is low enough that he will not have to shift again until the load is through that area. The gear selected should be low enough that the engine will run against the governors for the entire distance of the slope or marshy area. This will insure constant power to the wheels and will provide a margin of power so that, if the tires begin slipping, the operator can reduce the power to take advantage of the skidder momentum. In this manner he may get through the problem area without stopping. The operator should find the proper gear for each problem area on the first or second trip and use it thereafter.

Often, when forward motion is lost in a swamp or on a slope, and especially if traction is poor because of wet or loose soil, the

[1] Gibson, Harry G. ARTICULATED-FRAME, FOUR-WHEEL-DRIVE, TRACTOR STABILITY. Master's thesis, W. Va. Univ., Morgantown, W. Va. 125 pp. 1969.

skidder cannot get the load moving again. When this happens, it is often best to release the winch to free-wheeling and move the skidder farther along the skidroad, and then winch the load up to this position (fig. 5). Some skidder operators release part of their load under these conditions and proceed with the remainder; but this is not recommended unless the skidder is unable to winch the entire load through the problem area. The skidder operator should refrain from loading so heavily that this is necessary, especially if skidding distance is short.

If skidding distance is long and the segment of the skidroad that is causing problems is relatively short, winching the load through the problem area to bring in a larger load may prove to be more productive than skidding a smaller load.

The power shift or automatic transmission can also be helpful in problem areas. These transmissions permit the power-train ratio to be changed without a noticeable loss of forward momentum.

When skidding downhill, the skidder can be loaded more heavily, but this too must be watched and controlled closely by the operator, because forces are acting in a different direction on the skidder. A skidroad that is slightly downhill is best, but the operator is usually skidding on less than optimum slopes.

Figure 5.—Steep slopes and muddy areas often necessitate moving the wheeled skidder forward and then winching the logs to the skidder.

Descending a steep slope is dangerous, especially if the skidroad is sloped to one side. As the skidder starts down the steep slope, the logs should be lowered enough to require the engine to operate on a slight pull. Maximum control of the skidder on a steep downhill skidroad can be maintained by manipulating the winch controls to keep the load at the proper height. The operator should not attempt to slow the skidder by excessive use of the brakes. By using good judgement, a certain degree of caution, proper methods of skidder control, and by making an effort to become completely familiar with the particular skidding area or skidroad, the skidder operator can maintain good production from his skidder even on steep skidroads.

TRAVELING EMPTY

It is up the operator to select the proper engine r.p.m. and gear ratio according to the sound of the engine and the motion of the skidder on the empty return trip. Because of the hydraulic steering system, engine speed must be kept high for best steering control.

On skidders with mechanical transmissions, lost time and excessive wear and tear often result from poorly timed gear changes. And where rolling resistance is high, the skidder may come to a complete stop before shifting can be completed. When the distance to be traveled is short and the skidroad is such that shifting gears is a problem, it is best to run the entire trip in a lower gear.

The following technique requires much practice, but it is used by equipment operators for quick shifting into a higher gear. Accelerate until the skidder will not gain any more speed; slow the engine slightly; and, after a slight pause, rapidly release all pressure from the accelerator. Disengage the clutch just before the last pressure is released from the accelerator. As the clutch becomes disengaged, move the gear level quickly into the next gear, and, at the same time, place a slight load on the engine by activating the winch or blade. Activating the winch or blade places a load on the engine and aids in synchronizing the gears.

Gear shifting must be done as quickly as possible and must be timed perfectly, or the transmission gears can be damaged. If the

gears of the transmission clash, *do not force them;* either quickly shift into the original gear, or stop the skidder and start again.

The empty return trip provides an opportunity for the operator to view the skidroad and to consider repairs. Many minor repairs —such as removal of sharp rocks, snags, and dropped logs—can be made at the end of the day or when the skidder would otherwise be idle (fig. 6).

Water holes should be drained where it is practical. And where the soil is loose or soft, travel patterns should be chosen that prevent rutting and that aid in soil compaction—thereby adding to the quality of the skidroad. This also eliminates unnecessary tire wear and damage from ruts—especially important where the soil freezes.

Turning around on a slope is sometimes a problem. The front of the skidder is the heaviest and should be kept uphill when turning around on steep slopes. All quick turns uphill should be avoided, as this is the maneuver that has overturned many skidders.

Figure 6.—Scraping this skidroad during spare time kept ruts from forming and increased the traction for winching and skidding.

When a turn-around must be made where the ground is too steep for the skidder to leave the narrow skidroad, the forward and backward movement should be slow. Caution must be used here, because the full pivoting of the skidder frame may allow a wheel to get too near the edge of the skidroad.

USING THE BLADE

The wheeled skidder blade is designed primarily for piling logs at the landing (fig. 7). The blade is also useful for other tasks, but its value depends in large part upon the ability of the operator to adapt to the feel of the skidder. On most skidders, the operator's view of the blade is poor; therefore, the operator should select the blade corner that he can see best and use it, along with the sound of the engine, as a guide for lowering or raising the blade.

Helping to make or clear a landing may also be a part of the skidder operator's job. If large log stockpiles are to be handled

Figure 7.—The wheeled skidder is useful for piling logs and maintaining an orderly landing.

over an extended period, the landing should be graded to get a more even working surface, a location should be cleared for log piles, and ample area should be cleared for the loading activities.

The operator is responsible for insuring that the landing will drain properly. Should extended use of the site introduce new drainage problems, the skidder can be used to drain these areas and backfill them. This will aid the trucks that haul from the landing and keep the logs clean for the mill.

The skidder is not designed for moving earth, so earth-moving should be done with a crawler-type tractor. But small jobs can be done with the wheeled skidder if a crawler is not available.

Stumps at or near the landing should either be cut off as near the ground as possible or be completely removed, because the wheeled skidder will be making numerous trips over the landing area. While piling or moving logs, the skidder blade takes unnecessary punishment from stumps that are left too high.

When using the blade to move logs from one place to another on the landing, the operator can see the movements of the log and raise or lower the blade as necessary to maintain a rolling action. Logs can be piled with the wheeled skidder balde by keeping the blade parallel with the log and raising the blade with the log as it moves up the pile. Caution should be used in climbing the pile with the skidder because of the pile's instability. An orderly log pile can be maintained by piling the logs often so that there is always enough room for maneuvering the wheeled skidder.

PREVENTIVE MAINTENANCE TIPS

The service from a wheeled skidder is only as good as the preventive maintenance that it receives. The wheeled skidder operates under some of the most rugged conditions that a machine can be exposed to. Therefore, for the most successful use of a wheeled skidder, proper maintenance as well as operation is essential.

The manufacturers of wheeled skidders provide manuals that give in detail the required maintenance schedule that should be followed for each machine. The time spent studing these manuals will be repaid in a long and satisfactory life of the machine. Also,

the time spent in cleaning, adjusting, and greasing according to the manufacturer's recommendations will be more than repaid by savings in lost time and extra work.

To follow the manufacturer's daily maintenance recommendations precisely will require a lot of time at first. But, as the routine becomes more familiar, it will require less time.

Greasing fittings too heavily is a waste of grease and time, and may damage grease seals. A small amount of grease daily is much better than a large amount less often.

From observations on many logging sites, we have found that loggers tend toward one of two daily maintenance schedules: A small amount of preventive maintenance or no preventive maintenance. Few wheeled skidders are receiving the lubrication and preventive maintenance recommended by the skidder manufacturer.

For wheeled skidders, the purposes of lubrication are:

- To reduce friction.
- To remove foreign materials.
- To seal against entry of foreign materials.
- To cool.
- To prevent corrosion.

Although it is best if the manufacturer's recommendations are followed, here is a list that can be used for a daily routine. This list is not meant to replace the manufacturer's recommendations; but if it is followed, it will eliminate many of the problems that arise from insufficient maintenance.

Cleaning and checking

- ✔ Check the crankcase oil level.
- ✔ Check the radiator coolant level.
- ✔ Check the air cleaner for proper oil level and obstructions.
- ✔ Check the hour meter—clean the face and make sure it is working, as this is the only true indication of time since the last oil change.

- ✔ Check for loose bolts—particularly on the major components, such as the winch mounts, brake mounts, and oscillating axle points.
- ✔ Check for cracks in the skidder frame and at weld points.
- ✔ Check the mainline for weak points—it is easier to repair or replace at the landing than in the woods.
- ✔ Check tires for bad cuts—they are easier to repair before a flat occurs.

Lubricating

- ✔ Universal joints.
- ✔ Splined shafts.
- ✔ Steering cylinder bearings.
- ✔ Pivot pins of articulated frame.
- ✔ Axle pivot points.
- ✔ Blade support points.

THINK AHEAD

Following are some general guidelines for the wheeled skidder operator.

- ☞ Think ahead, and operate the skidder intelligently.
- ☞ Be completely familiar with the operating and service manuals supplied with your skidder.
- ☞ Be aware of nearby workers; you can help protect them.
- ☞ Be alert for accidents; they are usually man-made.
- ☞ The skidder is designed to withstand the forces necessary to skid logs, but it will break; handle it with care. Breadowns are costly.
- ☞ Discuss any problems or suggestions with your woods boss.

The effect of a single technique or procedure on total production of the operation may be small, but the influence of a number of

these small things add up to something big. Therefore, they should be treated by the operator as if each one of them could result in a large or even a prohibitive cost for the operation.

When it is realized what effect the skidder operation has on the entire logging job—on the welfare and saftey of the crew and on the profit margin of the operation—it is obvious that more attention to proper skidder operation is essential.

■

THE FOREST SERVICE of the U. S. Department of Agriculture is dedicated to the principle of multiple use management of the Nation's forest resources for sustained yields of wood, water, forage, wildlife, and recreation. Through forestry research, cooperation with the States and private forest owners, and management of the National Forests and National Grasslands, it strives — as directed by Congress — to provide increasingly greater service to a growing Nation.

A Guide to SUGARBUSH STOCKING

Based on the Crown Diameter/D.b.h. Relationship of Open-Grown Sugar Maples

FEB 10

by H. Clay Smith and Carter B. Gibbs

U.S.D.A. FOREST SERVICE RESEARCH PAPER NE-171
1970

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HOW MANY TREES?

SUGARBUSH MANAGERS have long needed a guide for determining the stocking of their sugar maple stands. The question is: for desirable sugar maple sap production, how many trees per acre are needed?

To provide information about stocking, the USDA Forest Service's sugar maple sap production project at Burlington, Vermont, has made a regionwide study of the relationships between crown diameter and d.b.h. (diameter breast high) of open-grown sugar maple trees (*Acer saccharum* Marsh.).

We found a strong relationship between crown diameter and d.b.h., and converted these data into stocking guides for various stand-size classes. The stocking guide are based on the assumption that trees with full crowns produce the best sap yields.

BACKGROUND

More than 20 years ago Cope (*1946*) pointed out the lack of published information about the management of woodlands for the production of maple syrup. This is still true today. Research information about the management of sugar maple trees for the production of sap is still limited.

One of the first topics mentioned in any discussion of sugarbush management is the number of trees per acre to leave after thinning. The spacing suggested for a sugarbush varies from 25 to 50 trees per acre, though some estimates exceed 100 trees per acre, depending on tree size (*Morrow 1955; Rudolph 1968*).

It is generally believed that the ideal sugarbush tree is one that has a deep, wide, fully developed crown, exposed as much as possible to sunlight (*Jones et al. 1903*). In essence, this is a description of an open-growth tree. Therefore we needed to know how large sugar maple trees grow, and then to relate the size of the tree crown to changes in tree diameter at d.b.h. for open-grown trees. A high correlation has been reported between crown width

and tree diameter for several species growing in the Central States (*Gingrich 1964*), but little information about sugar maple is available.

THE STUDY

For sampling purposes, we divided the sugar maple region into the following subregions according to climatic and geographic differences that could affect tree growth and development:

Subregion	*Area*
New England	Maine, New Hampshire, Vermont, and northeastern New York.
Mid-Atlantic	Southern New York, northern Pennsylvania, and northeastern Ohio.
Southern	Southern Pennsylvania, western Maryland, and eastern West Virginia.
Central	Southern Michigan, Indiana, and Illinois.
North Central	Iowa, Minnesota, and Wisconsin.

We selected 301 trees at random in several areas of commercial sugar production (fig. 1). The trees were single-stemmed and

Figure 1.—Location of sampling areas in the sugar maple survey.

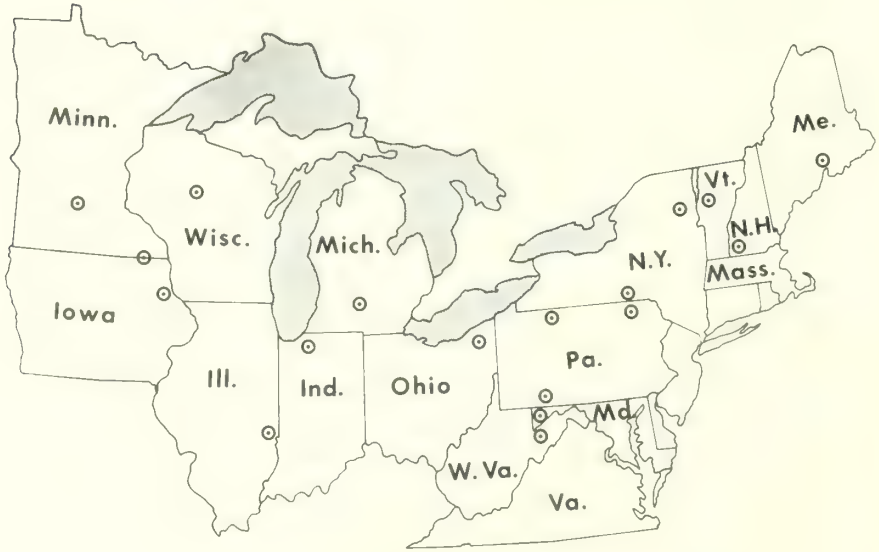

Figure 2. —Typical open-grown sugar maple trees.

open-grown, with no evidence of suppression or disease that might have impaired crown development (fig. 2).

Crown diameters were determined by using a perpendicular projection of the crown edge to the ground surface. The diameter of each tree crown was measured to the nearest 1.0 foot in north-south and east-west directions, and the two measurements were averaged.

Tree diameters were measured to the nearest 0.1 inch $4\frac{1}{2}$ feet above the ground on the uphill side of the tree.

RESULTS

The results of the regression analysis indicated that there is a strong correlation between tree diameter and average crown diameter.

Analysis of the data from the five subregions showed no material differences among subregions in the crown diameter/stem diameter relationship of open-grown trees. Thus only one equation was derived for the whole sugar maple region.

The regression equation and coefficient of determination (R^2) are as follows:

Equation	R^2
$Y = 12.08 + 1.32X$	0.84

where: Y = average crown diameter, and X = diameter at breast height. This equation was used to determine a guide to stocking natural and planted sugarbushes.

TREES PER ACRE

To determine the number of sugarbush trees per acre, we first computed the estimated crown diameter for trees of each d.b.h. class, using the regression equation. Then the area of the crown for trees of each d.b.h. class was determined, and this was converted to the number of trees per acre.

Natural stands.—The best stocking for natural stands of sugar maples growing in a forest condition was summarized by average stand-diameter class (table 1). Based on these data, stands with an average d.b.h. of 10 inches should have a minimum of 79 evenly distributed trees per acre. Stands that average 20 inches d.b.h. should have a minimum of 34 trees per acre.

Plantations.— The number of trees per acre was also computed for sugar maple plantations (table 1). There should be a minimum of 68 trees per acre in a sugar maple plantation having trees with an average diameter of 10 inches at breast height. A minimum of 29 trees per acre is recommended for sugar maple plantations with trees averaging 20 inches d.b.h.

An ideal plantation would have fewer trees per acre than a sugarbush developed from a natural forest stand. More trees are recommended for a natural stand because the trees are established at random. The area of a hexagon (distance between opposite sides equal to crown diameter) was used to compute number of trees per acre in natural stands. The position of trees in a plantation is fixed by planting in a grid system, so the number of trees per acre in plantations was computed by using the area of a square (length of sides equal to crown diameter).

Table 1.—Average crown diameter and minimum number of sugar maple trees per acre, by average stand-diameter class, for natural sugarbush stands and plantations

Average stand d.b.h. class	Average crown diameter	Trees per acre	
		Natural Stands	Plantations
Inches	*Feet*	*Number*	*Number*
4	17.4	167	145
6	20.0	126	109
8	22.6	98	85
10	25.3	79	68
12	27.9	64	56
14	30.6	54	47
16	33.2	46	40
18	35.8	39	34
20	38.5	34	29
22	41.1	30	26
24	43.8	26	23
26	46.4	23	20
28	49.0	21	18
30	51.7	19	16

SPACING AND BASAL AREA

The tree-spacing guide (table 2) can be used to determine the ideal distance between trees. First, determine the average number of trees per acre for the sugarbush stand, using table 1. For example, a natural sugarbush containing trees that average 14 inches d.b.h. should have a minimum of 54 trees per acre. Then, referring to table 2, note that the distance between the trunks of selected trees in a natural sugarbush with 54 trees per acre should be about 31 feet. However, these spacing values are ideal distances and may be difficult to attain under field conditions.

With any spacing guide, the question arises about what to do when the trees in the stand are not all the same size. For example, what should the spacing be between a 20-inch tree and a 12-inch tree in a natural sugar maple stand? To find the spacing distance, first average the d.b.h.'s of the two trees and then determine the

Table 2.—Spacing guide for number of trees per acre in natural and planted stands of sugar maple

Trees per acre		Spacing between trees	Trees per acre		Spacing between trees
Natural stands	Planted stands		Natural stands	Planted stands	
Number	*Number*	*Feet*	*Number*	*Number*	*Feet*
257	222	14	41	36	35
224	194	15	39	34	36
196	170	16	37	32	37
174	151	17	35	30	38
155	134	18	33	29	39
139	121	19	31	27	40
126	109	20	30	26	41
114	99	21	28	25	42
104	90	22	27	24	43
95	82	23	26	22	44
87	76	24	25	22	45
80	70	25	24	21	46
74	64	26	23	20	47
69	60	27	22	19	48
64	56	28	21	18	49
60	52	29	20	17	50
56	48	30	19	17	51
52	45	31	19	16	52
49	43	32	18	16	53
46	40	33	17	15	54
44	38	34	17	14	55

crown diameter and spacing for the average d.b.h. The average d.b.h. in this case is 16 inches, and the crown diameter is 33.2 feet (table 1). A natural stand containing trees 16 inches d.b.h. with a crown diameter of 33.2 feet should have 46 trees per acre (table 1). Thus there should be 33 feet between the two trees, because 46 trees per acre is equivalent to a 33-foot spacing (table 2).

An estimate of the minimum residual basal area per acre, based on the number of trees per acre, was computed for both natural stands and plantations (table 3). For example, natural sugar maple stands that have 79 trees per acre and trees that average 10 inches in diameter should be thinned to a residual basal area of approximately 43 square feet per acre. A similar stand of 10-inch

Table 3.—Recommended residual basal areas per acre for natural and planted sugar maple stands

Average stand d.b.h. class	Residual basal area	
	Natural stands	Plantations
Inches	*Square feet*	*Square feet*
4	15	13
6	25	21
8	34	30
10	43	37
12	50	44
14	58	50
16	64	56
18	69	60
20	74	63
22	79	69
24	82	72
26	85	74
28	89	77
30	93	79

trees in a plantation with 68 trees per acre should be thinned to a basal area of about 37 square feet per acre.

CONCLUSION

This sugarbush stocking guide was developed from a survey of the crown diameter/d.b.h. relationship of open-grown trees. It can be applied to sugar maple trees in undeveloped forest-grown stands, in overcrowded producing sugarbushes, and in plantations. The guide gives the minimum number of trees per acre and minimum residual basal areas for the various d.b.h. classes.

This information can be used as a basis for the improvement of both natural and planted sugarbuses throughout the regions of commercial maple syrup production.

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Use of HARDWOOD FLOORING in Mobile Homes

FEB 10 1971

by David G. Martens
and Leonard J. Koenick

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A Market Opportunity

THE HARDWOOD FLOORING industry is losing a new and vigorous market by default. The mobile-home industry produced over 250 million square feet of single-family housing space last year, and very little of this floor space was covered with hardwood flooring. A preliminary glance at this situation seems to uncover an industry that offers many opportunities for hardwood flooring manufacturers.

Why then is so little hardwood flooring being used? To learn more about this growing industry and to discover some of the factors that now limit the use of hardwood flooring, a series of discussions were held with executives in the industry.

The Industry in General

The production of mobile homes has increased from 150,840 units just 6 years ago to 395,000 units in 1969, and is expected to exceed 465,000 units in 1970. This means that one out of every four single-family housing starts is now a mobile home. The industry has captured 80 percent of the market for houses under $15,000. And this growth is happening in the face of a severe slump in the building of conventional residential housing.

The average size of mobile homes has been increasing steadily: today three-fourths of all mobile homes are at least 12 feet wide. Greater interest is being shown in sectional housing, in which two or more units are joined to form a single larger home. Ways of

using existing mobile-home manufacturing facilities to produce modules for apartments and town houses that meet FHA and local building-code standards are developing rapidly.

At the time of this study only one manufacturer was found who offered strip flooring in his mobile homes; and he may stop in the near future. About a dozen manufacturers use parquet in some of their homes — most commonly in the dining area but rarely throughout the home. Some manufacturers who build custom homes have used strip flooring on request.

Limiting Factors

Use of hardwood flooring in mobile homes is limited by manufacturing problems and marketing problems. Both are considered critical; and both require attention if hardwood flooring is to be sold to the mobile-home industry.

MANUFACTURING

The floor construction of a typical mobile home differs little from its conventional counterpart. Floor supports are usually nominal 2- by 4-inch (sometimes 2- by 5-inch or 2- by 6-inch) joists spaced on 16-inch centers. The subfloor is usually $\frac{5}{8}$-inch plywood installed in 4- by 8-foot sheets — even in 10- by 12-foot wide homes. However, some manufacturers use 4- by 10-foot and 4- by 12-foot sheets. The higher cost per square foot for the larger sheets is offset by greater installation speed and lower labor costs.

After the subfloor is in place, the plumbing is installed and the plywood joints are sanded and often taped to prevent the edges from telegraphing through the finished floor.

In most homes, resilient flooring is installed before any walls, exterior or interior, are erected. This gives the workmen an unrestricted work area, and requires a minimum of cutting and fitting. Much of the carpeting is also laid before any walls are up; especially when the entire home is carpeted. In some cases, the carpet is installed just before the furniture is placed, and occasionally the dealer installs the carpeting at his lot.

Speed and Timing

The speed with which the finish floor can be installed is critical, becase mobile homes are constructed on an assembly line, where each operation must be done within the time allotted for each station.

Most resilient flooring and carpeting is delivered in rolls 12 feet wide. The rolls are suspended above the work station and are unrolled like paper towels. In high-speed operations, the mastic is sprayed on the subfloor; and a complete finished floor can be installed in less than 15 minutes. Individual tiles, of course, take longer to install; but still a complete 12- by 60-foot platform can generally be covered by two men in 40 minutes.

The one manufacturer who offered hardwood strip flooring said that installation time was one of his biggest problems. The flooring was laid directly on the joists, without a subfloor, and it took between 6½ and 7 man-hours to do the job. Several hardwood flooring contractors contacted during this study estimated that a 12- by 60-foot floor would take about 10 man-hours — the estimates ranged from 8 man-hours to 16 man-hours.

Hardwood strip flooring cannot compete with the other flooring products in speed of installation. However, it could compete if it were panelized into larger units. Although the rapid installation speeds for resilient and carpet floor coverings are impressive, the time to install both the plywood subfloor and the finish floor covering is the correct time to use for comparison with strip flooring. On this basis, panelized hardwood strip flooring would be able to compete.

Thickness

With standard strip flooring 25/32-inch thick, there would be no problem with added thickness, because the plywood now used is ⅝-inch thick, and with the addition of the carpet or tile the total thickness is about ¾ inch. Therefore switching to strip flooring would not cause production difficulties due to differences in flooring thickness.

Labor

All manufacturers believed that their present employees could install strip flooring. Several said that there would of course be a short period of slow installation while the workmen became proficient, but all agreed that this would be of no consequence.

Handling and Storage

All manufacturers said they would be able to store hardwood flooring inside. Conventionally packaged strip flooring would present no unusual handling problems. Panels of flooring, however, might present problems. Depending on the size of the panels, new handling equipment might be needed.

Availability

Mobile homes are produced on a year-around basis; seasonal fluctuations in the production rate are small. This means that, contrary to the normal construction patterns, flooring producers selling to the mobile-home industry must be able to supply flooring at a constant rate during the year. Since the production rate is predictable and non-cyclical, long-term contracts for flooring could be negotiated to insure availability to meet production schedules.

Weight

The mobile home of today is a solidly constructed product able to support a considerable load. An early fear held by people in the wood-products industry was that the weight of hardwood flooring would preclude its use in mobile homes. This is definitely not so for most of today's homes.

Hardwood strip flooring in its conventional form would add about 50 pounds per 100 square feet of floor area. The standard subfloor is 5/8-inch fir plywood, and on top of this lies the finish floor, either carpet or resilient flooring. This gives a total weight of about 240 pounds per 100 square feet (5/8-inch fir plywood at 170 pounds; carpet and pad at 70 pounds). Conventional 25/32-inch strip flooring weighs about 290 pounds per 100 square feet.

The weight difference of 50 pounds per 100 square feet is equal to about 360 pounds evenly distributed over a 12- by 60-foot home.

Weight is important primarily when the mobile home is being transported. Some manufacturers expressed concern that the additional weight might require sturdier and more expensive running gear for the homes in the highly competitive low-price range.

However, in the near future an increasing percentage of homes will be transported either on removable axles or on flatbed trucks. The traditional idea that a mobile home is self-contained and easily transportable is rapidly being forgotten. Several factors are acting to hasten this change. The most obvious is size. A modern 12- by 65-foot home requires special hauling vehicles, special preparation, and special permits for hauling. Because the producing industry is becoming dispersed geographically, shorter hauling distances are possible. Recent studies show that mobile homes are moving shorter distances and are staying longer. Added to these trends is the growth of modular and sectional housing.

Strength

The floor of a mobile home serves two structural purposes. First, the floor must support any reasonable loads placed on it. Second, the floor must be firm, so it feels safe and comfortable.

Recent tests conducted at Virginia Polytechnic Institute showed that standard tongue-and-groove oak flooring (25/32-inch thick) — without a subfloor — is more than strong enough to span the 16-inch space between the joists.

The floor in a mobile home also adds stiffness to the frame. Acting as a skin, the floor allows the frame to serve as a boxed beam or hollow column. This is important during transportation because of the unusual stresses that occur. Oak flooring is more than strong enough to withstand such stresses.

Flexibility

A mobile home is subjected to unusually high stresses during transportation. Any flooring product must be able to withstand the flexing and wracking that occur as the home is moved.

The Mobile Home Manufacturers Association has recently approved construction standards of minimum structural design requirements for in-transit conditions. The one manufacturer now offering strip flooring said that he has never had any problems with his flooring as a result of transit conditions.

Dimensional Stability

The moisture conditions found in mobile homes may present problems in keeping hardwood flooring dimensionally stable. Although some homes are built only on order, most remain on a dealer's lot for an undetermined amount of time. During this period, there will be little ventilation and no heat in the homes. Many mobile homes that are used as second homes will also be closed for long periods of time.

The moisture problem unique to mobile homes is due to their transportability. A mobile home may be built in one climate and moved to another. The resulting change in moisture conditions will affect all wooden parts of the home. The trend towards decentralization of manufacturing plants may help to reduce this problem due to movement from one climate to another.

Repair

Since the finish floor in a mobile home is usually installed early in the construction process, it is often exposed to possible damage. The flooring must be easy to repair, and the repair must be acceptable to the consumer. There should be no easily visible sign that a repair has been made. A repair made before the consumer has seen the damage is rarely noticed. However, several manufacturers said that if they make the same repair after a home is sold, the consumer usually complains that the repair is too visible.

Resilient tile floors are easily repaired by replacing the damaged tiles. However, slight changes in color between batches of tile sometime occur. Resilient sheet goods also are easily repaired. Many random designs may be patched without visible pattern changes, and flooring with a symmetrical pattern is repaid by

replacing matched sections. Again, slight color differences may occur.

Hardwood flooring can also be effectively repaired, but it takes a little longer. Generally the hardwood flooring installed in a mobile home is prefinished, and any damage to the floor requires that the damaged area be refinished. Some mobile-home manufacturers use an inexpensive protective mat or paper to cover and protect the floor while the remainder of the home is being built, thereby avoiding the need for repair.

MARKETING PROBLEMS

The major marketing problems that inhibit the use of hardwood strip flooring appear to be (1) the maintenance and wear-life image that the mobile home industry has tried to create, (2) the erratic and unpredictable price patterns for hardwood flooring, and (3) the apparent lack of expressed demand by the mobile-home buyer for hardwood flooring.

Wear-Life and Maintenance Image

Mobile homes are promoted as a low-maintenance product. The industry has spent a lot of time and money to create this image. Two components have been stressed consistently in this promotion: aluminum siding and resilient flooring. Since the industry has successfully built the image of resilient flooring as a low-maintenance product, it has a vested interest in using resilient flooring.

A recent study,[1] in which maintenance costs of three types of residential flooring were compared, showed that hardwood floors are cheaper to maintain than either carpeting or resilient flooring. The annual maintenance cost per 100 square feet of hardwood flooring was $4.21 while the cost of maintaining composition tile was $9.89 and the cost of maintaining carpeting was $8.27.

This study also verified the long wear-life of hardwood floors and the shorter lives of carpeting and resilient flooring. The

[1] David G. Martens. FLOORING COSTS—A COMPARISON OF INSTALLATION AND MAINTENANCE COSTS FOR THREE TYPES OF RESIDENTIAL FLOORING. USDA Forest Serv. Res. Paper NE-124. NE. Forest Exp. Sta., Upper Darby, Pa. 23 pp., 1968.

wear-life of flooring materials should become more important as the average life of mobile homes increases. Certainly, with stacked modular units, the flooring material must not wear out. This is especially important because mobile homes are sold principally to lower income families on high-interest-rate loans. Also, the recent use of mobile homes in urban renewal for low-income housing requires long-lived materials with low maintenance costs. Low-income families will be least able to replace rapidly worn-out flooring and still maintain their mortgage payments.

Ordering and Pricing Practice

The market structure of the mobile-home industry requires stable prices for raw materials. Historically, the prices for hardwood flooring have been erratic. Though this price fluctuation has caused problems in the conventional housing market, it will be particularly acute in the mobile-home industry.

Because the mobile-home industry is highly competitive, costs must be watched and controlled carefully. Homes are designed for specific price brackets. Changes in the price of raw materials may increase the cost of the home beyond the price bracket for which it was designed; and then the manufacturer is forced to absorb the loss. The fact that there is an established dealer network within the mobile-home industry also makes fluctuations in the price of raw materials more critical. A large percentage of mobile homes are built only on receipt of dealer orders. These orders represent firm commitments at a given price. Consequently any increase in price is absorbed by the manufacturer. Given the highly competitive nature of the industry, these losses are not easily regained.

Consumer Preferences

No interviews were conducted with consumers during this study, because this type of information is available from previous studies. However, industry executives did express their understanding of consumer preferences.

Just as manufacturers are accustomed to using synthetic flooring

materials, most consumers also are conditioned to expect synthetic flooring for mobile homes because they have seldom if ever seen mobile homes with hardwood floors. Thus they have little expectation of hardwood flooring and would not be expected to ask for it.

Another factor that influences consumer preference is the image carried by the flooring in the mind of the consumer. The mobile home is a totally planned environment. The interior decor of the mobile home emphasizes fashion and style. The selling image is "modern". Carpeting and resilient flooring both fit this image.

Hardwood flooring, on the other hand, has an image characterized by traditional, quality, practicable, and durable. Some industry people feel that this image could be marketed effectively. They believe that hardwood flooring could enhance the image of a mobile home by association with higher quality conventional construction. For example, doors and windows in mobile homes are often advertised as being "house type".

A recent survey of owners' preferences for floor coverings showed an underlying preference for hardwood flooring in mobile homes. In the survey, conducted for *Mobile Life Magazine*,[2] mobile-home owners were asked about their choice of floor coverings. The following response was obtained:

Floor Covering Preference	*Percent*
Vinyl or composition tile	15.4
Linoleum or composition sheet	2.7
Carpeting throughout	4.8
Combination carpeting and tile	56.1
Combination carpeting and sheet material	5.4
Hardwood throughout	1.0
Combination hardwood and carpeting	9.5
Combination hardwood and tile	4.1
Other	1.0
	100.0

Lifting out only those preferences for some use of hardwood flooring, we find that about 15 percent of those interviewed pre-

[2] Carl Edwards. MOBILE LIFE CONSUMER SURVEY—MOBILE HOMES. Mobile Life Mag., New York, N.Y. 41 pp. illus. [n.d.]

ferred hardwood flooring. At first glance this is a low figure. However, far less than 1 percent of existing mobile homes have any hardwood flooring. Also, dissonance theory teaches that people are apt to favor what they already have. Since very few of the respondents would have ever seen hardwood flooring in a mobile home and even fewer would be living on it, the strength of the 15 percent is greater than it first appears.

Summary

A potential market for hardwood strip flooring does exist in the mobile home industry. Of the manufacturing problems, the slow rate of installation appears to be the most critical in limiting the use of strip flooring. Product modification, such as panelizing, appears most promising as a solution to this problem. Thickness, labor, handling and storage, availability, weight, strength, flexibility, dimensional stability, and repair are of only minor importance.

The marketing problems center around the attitudes and preferences of the mobile home manufacturers as well as the buyers. Hardwood flooring is a low-maintenance-cost product, and it does have a long wear-life. The underlying consumer preference for hardwood flooring can be stimulated through education and promotion. Pricing practices could also be modified through the use of contracts or purchasing agreements to make it easier for the mobile-home manufacturer to control his costs and ordering schedules.

Hardwood strip flooring has traditionally been accepted as a superior residential flooring product. Mobile homes now represent over 25 percent of the new single-family homes being built, and they must be considered a potential market for hardwood flooring.

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THE FOREST SERVICE of the U. S. Department of Agriculture is dedicated to the principle of multiple use management of the Nation's forest resources for sustained yields of wood, water, forage, wildlife, and recreation. Through forestry research, cooperation with the States and private forest owners, and management of the National Forests and National Grasslands, it strives — as directed by Congress — to provide increasingly greater service to a growing Nation.

Effect of THINNING *on Height and Diameter Growth of* OAK & YELLOW-POPLAR SAPLINGS

UNIVERSITY
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NORTHEASTERN FOREST EXPERIMENT STATION, UPPER DARBY, PA.
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Effect of THINNING *on Height and Diameter Growth of* OAK & YELLOW-POPLAR SAPLINGS

What Effects from Thinnings?

THINNINGS ARE an integral part of even-aged management for efficient and profitable production of timber products. Thinnings started at an early age in hardwood stands increase value yields and reduce rotation age by concentrating growth on selected stems.

It is generally believed that thinnings stimulate diameter growth of the residual stems, but have little, if any, effect on height growth. Hebb (*1962*) and Ward (*1964*) stated that height growth and height are relatively unaffected by density. On the other hand, Larson (*1963*) and Smith (*1962*) reported that there is some evidence that density has a definite effect on height growth, especially at very low and possibly at very high densities.

Studying the response to thinning of a 7- to 9-year-old upland hardwood sapling stand, we found that height growth of yellow-poplar and oak trees was markedly reduced by heavy thinning. This suggests that stand density should be carefully controlled to achieve maximum benefit from thinnings in very young stands.

Study Area & Methods

THE EXPERIMENT

Our study was established in 7- to 9-year-old even-aged hardwood stands on the Vinton Furnace Experimental Forest in southeastern Ohio. These stands, which emerged after clearcutting, contain a wide variety of upland hardwood species.[1]

The study consisted of four blocks of plots having residual density levels of 10, 30, 50, 70, and 100 percent stocking[2] assigned at random to plots within blocks. No thinning was done in the 100-percent stocking plots; all other plots were thinned to the required density level. Data are based on 668 trees: 73 dominant or codominant oaks, 202 dominant or codominant yellow-poplars, 162 intermediate or suppressed oaks, and 231 intermediate or suppressed yellow-poplars.

THINNING METHOD

Initial thinnings were made in the winter of 1962-63, to achieve as uniform spacing between residual trees as possible. In general, the less desirable species[3] such as dogwood, sumac, sassafras, red maple, and blackgum—and the lower crown classes of all species —were removed first. However, many stems of less desirable species and lower crown classes had to be left to maintain uniform spacing. Thus the residual stand included stems of both desirable and undesirable species of all crown classes.

During the growing seasons of 1963 and 1964, sprouting from stumps of trees removed in the lower density plots was prolific, and these sprouts grew rapidly. This resulted in the 10-percent stocked plots increasing to almost 52 percent stocking, while the higher density plots increased proportionately less. So the plots were thinned again before the 1965 growing season to maintain

[1] See appendix for stand composition.

[2] Percent stocking was calculated using Gingrich's (*1967*) formula (tree area in milacres $= -0.0507N + 0.1698\Sigma D + 0.0317\Sigma D^2$) modified to eliminate the negative intercept by forcing the curve through the origin, thus accommodating trees of small diameter.

[3] See appendix for listing of common and scientific names of all trees referred to in this study.

the prescribed density levels. In some of the lower density plots, sprouts from desirable species cut in the first thinning were retained to readjust stocking and spacing. These sprouts were used only to replace residual stems that had died. Although not as tall as the dead residuals, they were vigorous, free to grow, and were judged likely to become a permanent part of the stand.

MEASUREMENTS

Height was measured with a telescopic pole, to the nearest 1/10 foot, and diameter at breast height was measured to the nearest 1/100 inch with a diameter tape. Measurements on residual trees were made each fall after growth had stopped, over a 3-year period.

DATA ANALYSES

Differences among stocking levels in diameter and height growth were tested for significance, using the analysis of covariance, with original d.b.h. as the covariate so the effect of original d.b.h. could be removed. Analyses were performed on seedlings and seedling sprouts only, for all oak species combined, and for yellow-poplar. Separate analyses were made for the dominant and codominat trees as a group, and for the intermediate and suppressed trees as a group for each genus. Differences between the adjusted means were highly significant in each analysis. Multiple-regression equations were derived for predicting the growth rate from stocking level and initial diameter. The adjusted mean growth and the multiple-regression lines are shown in figures 1 and 2. Predicition equations and coefficients are listed in the appendix.

Figure 1.—Effect of stocking level on diameter growth of 7- to 9-year-old saplings. Values have been adjusted for the covariate initial diameter. See appendix for regression formulae.

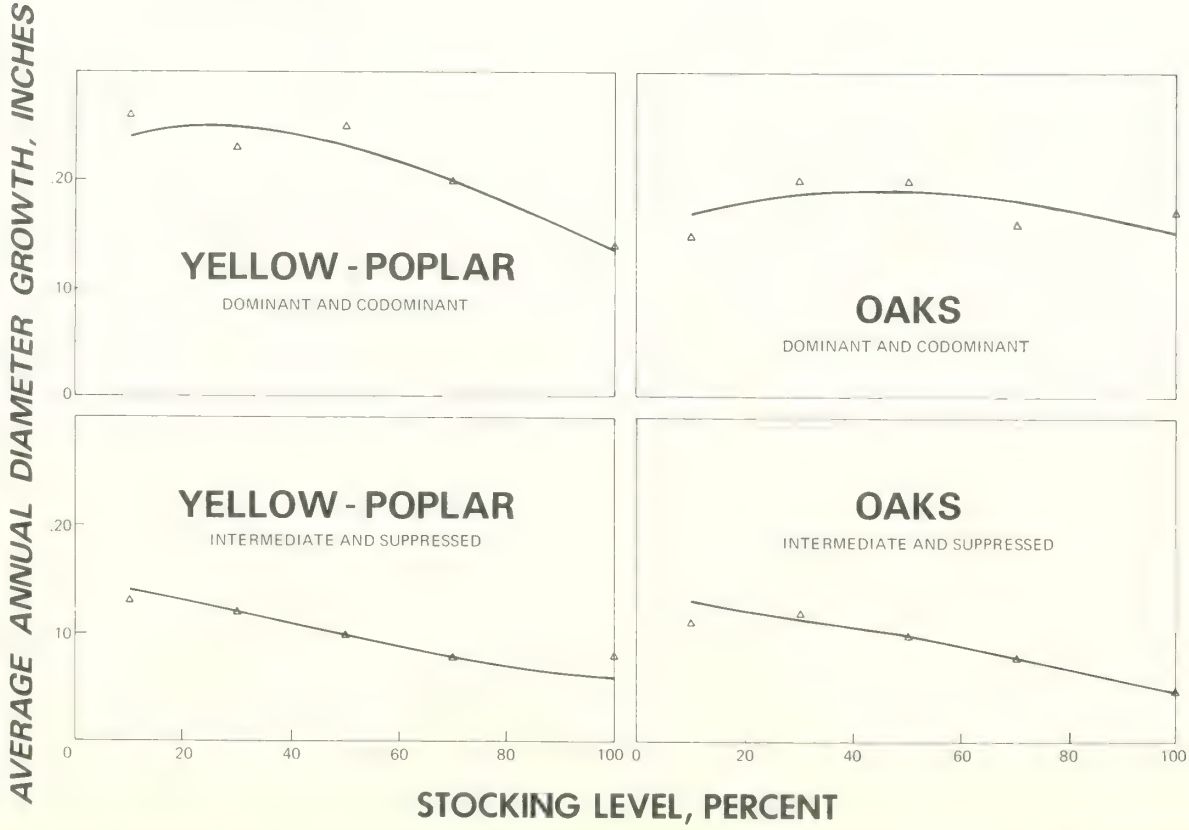
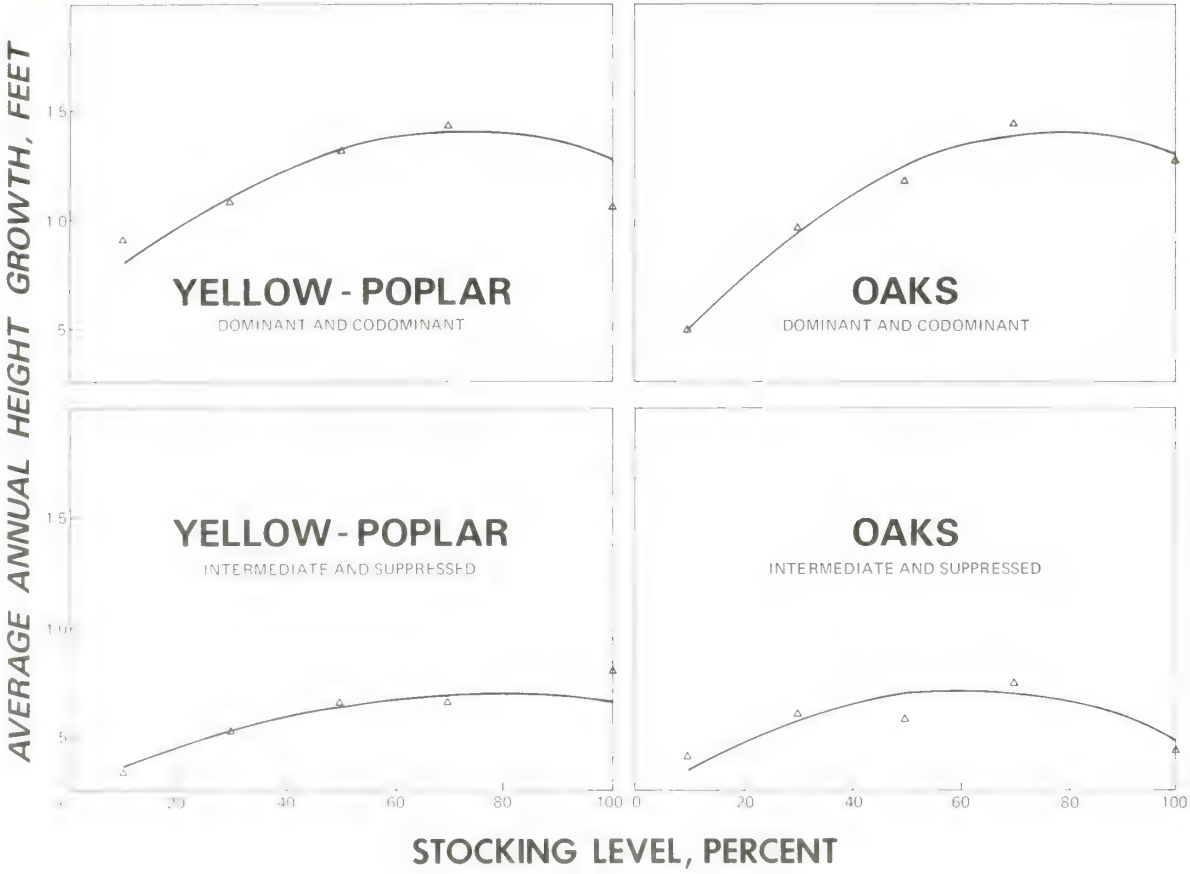


Figure 2.—Effect of stocking level on height growth of 7- to 9-year-old saplings. Values have been adjusted for the covariate initial diameter. See appendix for regression formulae.



Results & Discussion

Both diameter and height growth were significantly affected by initial diameter. The larger the initial tree diameter, the faster a tree grew.

Diameter growth of individual trees generally increased as stand density (stocking level) decreased. Greatest diameter growth occurred at the lowest density studied (10-percent stocking) for intermediate and suppressed trees of both yellow-poplar and the oaks. The dominant and codominant trees followed a similar pattern except that diameter growth dropped slightly at the 10-percent stocking level. Best diameter growth occurred at stocking levels of 50 percent or less for all species and crown classes (fig. 1).

We found that height growth of the individual trees of all crown classes and species was generally best at about 70-percent stocking. At higher stocking levels, height growth dropped slightly; but at lower stocking levels, height growth was markedly reduced. This reduction in height growth at lower densites was especially severe for the dominant and codominant stems (fig. 2). This variation in height growth due to density was made readily apparent by the extreme ranges in density studied. This effect may appear to be random or even non-existent when applied to the smaller range of densities appearing in unthinned or lightly thinned stands.

Although we have not included the data for red maple within the range of densities where it was present, it followed the same general growth patterns as yellow-poplar and the oaks.

Dominant and codominant trees grew faster in both height and diameter and showed greater absolute response to thinning than intermediate and suppressed trees. Nevertheless, the intermediate and suppressed trees did respond to thinning in essentially the same manner as their larger associates.

Conclusions

It is apparent from this study that maximum diameter growth and maximum height growth of young hardwood saplings occur at different levels of stand density. Thinnings that are too heavy will result in loss of height growth; thinnings that are too light will increase diameter growth little, if any.

Maximum height growth generally occurred at about 70 percent stocking; thinning to this density will stimulate both diameter and height growth as compared to unthinned trees. Thinning more heavily generally increases diameter growth further, but reduces height growth. Since very heavy thinnings also tend to increase stem taper, delay natural pruning, stimulate epicormic branching, and otherwise reduce overall tree quality, it is generally desirable to avoid thinnings that reduce density below about 50-percent stocking. As a general rule, we recommend 60-percent stocking as a useful compromise. Both height and diameter growth are acceptable at this level, and stem quality should not be adversely affected.

To minimize costs, some form of crop-tree thinning should be used when thinning sapling stands. In such thinnings, it is the density around the individual crop trees that is important, rather than overall stand density. Total release of crop trees (as in thinning to a specific radius) could reduce height growth even though density of the stand as a whole may be high.

In thinning sapling stands, the larger, dominant, and codominant trees of desirable species should be favored where possible. They respond better to thinning than do the smaller, intermediate, and suppressed trees.

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Appendix A

Stand composition of sapling hardwood stands before thinning

Species	Stems per acre	Percent of total	Basal area per acre	Percent of total	Percent stocking
	Number	*Percent*	*Square feet*	*Percent*	*Percent*
Yellow-poplar	1,105	12.2	6.94	18.9	19.3
All oaks[1]	525	5.8	2.78	7.5	8.3
Red maple	1,200	13.2	6.90	18.8	18.9
Blackgum	425	4.7	2.39	6.5	6.8
Hickory	480	5.3	1.54	4.2	6.0
Cherry	125	1.4	1.79	4.8	3.2
Miscellaneous[2]	70	.8	1.11	3.0	1.9
Total, trees	3,930	43.4	23.45	63.7	64.4
Dogwood	3,510	38.8	9.02	24.5	34.9
Other brush[3]	1,615	17.8	4.32	11.8	17.4
Total, brush	5,125	56.6	13.34	36.3	52.3
All species	9,055	100.0	36.79	100.0	116.7

[1] White, chestnut, black, scarlet, and northern red oaks.
[2] Aspen, elm, ash, sugar maple, persimmon, and beech.
[3] Sumac, hazelnut, witchhazel, sassafras, sourwood, alder, and chestnut.

Appendix B

List of common and scientific names of species referred to in this study.

Alder, common	*Alnus serrulata* (Ait.) Willd.
Ash, white	*Fraxinus americana* L.
Aspen, bigtooth	*Populus grandidentata* Michx.
Beech, American	*Fagus grandifolia* Ehrh.
Blackgum	*Nyssa sylvatica* Marsh.
Cherry, black	*Prunus serotina* Ehrh.
Chestnut, American	*Castenea dentata* (Marsh.) Borkh.
Dogwood	*Cornus florida* L.
Elm, slippery	*Ulmus rubra* Muhl.
Hazelnut	*Corylus americana* Walt.
Hickory spp.	*Carya spp.* Nutt.
Maple, red	*Acer rubrum* L.
Maple, sugar	*Acer saccharum* Marsh.
Oak, black	*Quercus velutina* Lam.
Oak, chestnut	*Quercus montana* Willd.
Oak, northern red	*Quercus rubra* L.
Oak, scarlet	*Quercus coccinea* Muenchh.
Oak, white	*Quercus alba* L.
Persimmon	*Diospyros virginiana* L.
Sassafras	*Sassafras albidum* (Nutt.) Nees
Sourwood	*Oxydendrum arboreum* (L.) D. C.
Sumac, smooth	*Rhus glabra* L.
Sumac, staghorn	*Rhus typhina* L.
Witchhazel	*Hamamelis virginiana* L.
Yellow-poplar	*Liriodendron tulipifera* L.

Appendix C

Prediction equations for diameter and height growth.

DIAMETER GROWTH	$\bar{D}$	R^2
Yellow-poplar, dominant & codominant		
$d = 0.2299 + 0.2824\bar{D} + 0.0031S - 0.000063S^2$	1.668	36.5
Yellow-poplar, intermediate & suppressed		
$d = 0.2245 + 0.2819\bar{D} - 0.0029S + 0.000003S^2$	0.771	34.1
Oaks, dominant & codominant		
$d = 0.0541 + 0.324\bar{D} + 0.0034S - 0.000037S^2$	1.355	48.0
Oaks, intermediate & suppressed		
$d = 0.1848 + 0.2738\bar{D} - 0.0016S - 0.000009S^2$	0.774	42.7
HEIGHT GROWTH		
Yellow-poplar, dominant & codominant		
$h = 0.2561 + 0.9691\bar{D} + 0.0650S - 0.00045S^2$	1.668	27.3
Yellow-poplar, intermediate & suppressed		
$h = -0.2116 + 1.3697\bar{D} + 0.0314S - 0.0002S^2$	0.771	13.1
Oaks, dominant & codominant		
$h = 0.3172 + 0.2291\bar{D} + 0.0915S - 0.00058S^2$	1.355	29.7
Oaks, intermediate & suppressed		
$h = -0.7308 + 1.6792\bar{D} + 0.0522S - 0.00043S^2$	0.774	20.5

where d = 3-year diameter growth, h = 3-year height growth, $\bar{D}$ = average of the initial diameters as shown in the column at the right, and S = value of stocking level in percent.
R^2 = Coefficient of determination (percent).

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MINI-ROTATION FORESTRY

[illegible]

by Ernst J. Schreiner

U.S.D.A. FOREST SERVICE RESEARCH PAPER NE-174
1970

NORTHEASTERN FOREST EXPERIMENT STATION, UPPER DARBY, PA.
FOREST SERVICE, U.S. DEPARTMENT OF AGRICULTURE
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ERNST J. SCHREINER, principal forest geneticist, received his bachelor's degree from the New York State College of Forestry at Syracuse in 1926, and his Ph.D., with a major in genetics, from the Faculty of Pure Science of Columbia University in 1931. In April 1924, shortly before the end of his Senior year, he accepted employment as research forester to start the Cooperative Oxford Paper Company—New York Botanical Garden Poplar Hybridization Project under the supervision of Dr. A. B. Stout, plant geneticist at the Botanical Garden. In 1935 he accepted the post of associate tree-crop specialist with the Forestry Division of TVA to initiate breeding work with tree-crop species. He joined the USDA Forest Service's Northeastern Station in New Haven, Connecticut, in 1936 and began the Forest Service tree-breeding research in the Northeast. Within the past 7 years he has been appointed adjunct professor of forestry at the State Universities of New Hampshire and Pennsylvania. At present he is stationed at the Northeastern Station's Forestry Science Laboratory in Durham, New Hampshire.

Dr. Schreiner has had wide foreign experience, including advisory assignments on quinine breeding in Guatamala and on poplar breeding and forest genetics in Yugoslavia, a 1-year Fullbright Research Fellowship in Europe on poplar culture and forest genetics, and an FAO consultant assignment on plant gene resources. He has had an active part in eight international conferences on forestry and forest genetics. He is a Fellow of the Society of American Foresters.

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Mini-Rotation Forestry

A paper presented at the spring meeting of the Northeastern Technical Division of The American Pulpwood Association, at Gorham, New Hampshire, 26 May 1970.

IT HAS BEEN SAID that there is nothing new under the sun; and originality has been defined as the art of remembering what you hear and forgetting where you heard it. This paper is an attempt to utilize ideas, predictions, estimates, and facts from many sources to chart a possible avenue of approach for future production of fiber and timber in the Northeast.

I am not an economist and will not attempt to predict forestry's future economic environment. It has been said that, if all the economists in the world were laid end to end, they would still point in all different directions. I will quote briefly four economists who are pointing in the directions I like.

Pointing to the Future

Fedkiw (*1970*), writing about *Forestry's Changing Economic Environment,* noted that, "Forestry will have to go all out for genetically superior trees, fertilization, stocking and brush control, sycamore silage, highly intensified utilization, and other new technologies." And he added that, "There has never been a greater need for enlightened leadership and exploding innovations in forestry practice."

According to Wheeler (*1960*), the report of the Southern Resource Analysis Committee, titled *The South's Third Forest,*

includes an estimate that some 10 million acres of forest land in the South will be withdrawn for agriculture, urban expansion, rights-of-way, reservoirs, recreation, and other uses by the end of the century.

Drysdale (*1969*) hazards a guess that, by the year 2010, Canada will be retiring about one-third of its most expensive and least productive forest sites from the production of commercial wood products to concentrate major wood-production efforts on forest lands that have the best combination of productive capacity, accessibility, and proximity to markets.

How much forest land will be available for *profitable* timber production in the Northeast by the end of this century?

The key to continued and increased production of wood and fiber in the Northeast may well be the private landowners; their lands are usually the most accessible and most productive areas available for intensive forest culture.

Fields (*1969*) reported that a recent survey conducted by the Tennessee Valley Authority in the seven Tennessee Valley States indicated that approximately 139 thousand acres of private forests were already under long-term lease to a forest industry or some other party. More important, owners of almost 4 million acres said they might be interested in such an arrangement.

Swan (*1969*) has presented a dim picture of the availability of woods labor in the Northeast at present; and there is no reason to expect that it will improve in the future. He notes that young men can be recruited and trained to operate logging equipment—but by logging equipment I assume that he means only heavy equipment, not the chain saw. How much chain-saw labor will be available for the harvesting of fiber and timber in 1980? And how much will it cost?

Drysdale (*1969*) has suggested that in Canada during the next 40 years there will be a gradual switch from a single-tree harvesting system, in which the size of the individual tree is economically important, to a multi-tree system that depends more on the total volume per acre and provides an opportunity to take advantage of shorter rotation periods. We will not have as much as 40 years to effect such a change in our Northeast.

THE NEED FOR INTENSIVE SHORT-ROTATION FORESTRY

The probability of a shortage of softwoods in the Northeast for fiber and lumber is generally admitted. Although we are already aware of a serious shortage of quality logs for the hardwood lumber industry, it appears to be the general opinion that there will be no shortage of hardwood for conversion to fiber. Can we count on this? The hardwood will be here 10 or 20 years from now, but it is highly probable that a combination of the lack or high cost of chain-saw labor to harvest forest crops on the steep terrain in this region, and public pressure against clearcutting of the lowland forest areas visible from practically all of our highways, will result in a short and expensive supply of hardwood fiber.

We are now harvesting our Fourth—practically unmanaged—Forest. The First Forest was harvested with ax and oxen; the Second with the two-man saw, horses, and narrow-gage railroads; the Third with the buck saw, horses, and tractors; and the Fourth is now being managed and harvested with the chain-saw and tractors.

The Fifth Forest of the Northeast will have to be managed intensively. And it will have to be established, cultured, and harvested by machine.

The length of rotations in our Fourth Forest of the Northeast under *present* management recommendations for *present* utilization requirements are indicated in tables 1 and 2.

Table 1.—Years to reach a given mean diameter, by site index for managed (thinned) stands of mixed northern hardwoods [1]

Mean d.b.h. (inches)	Site index		
	70	60	50
	Years	*Years*	*Years*
5.0	33	38	44
9.0	62	77	93
15.0	118	—	—

[1] Excerpt from William B. Leak *et al.* (*1969, p. 20*).

Table 2.—Expected rotation ages and sizes for stands under management [1]

Species and objective	Paper birch site index (height at b.h. age 50)	Average diameter[2]	Age
	Feet	*Inches*	*Years*
Paper birch boltwood	70	9	45
	50	8	65
Paper birch sawtimber	70	11	65
	50	9	75
Other hardwoods sawtimber	70	15	120
	50	11	135
Spruce-fir pulpwood	70	9	65
	50	8	75
Spruce only, sawtimber	70	14	120
	60	13	135

[1] Excerpt from David A. Marquis *et al.* (*1969, p. 40*).
[2] Average diameter of the species shown, not of the entire stand.

Table 1 gives estimates of the years to reach a given mean diameter, for managed (thinned) stands of mixed northern hardwoods. Estimates for a mean stand diameter of 5 inches are 33 years (site 70) to 44 years (site 50); for a 9-inch mean stand diameter, 62 years (site 70) to 93 years (site 50); and for a 15-inch mean stand diameter, 118 years on site 70.

Table 2 lists the expected rotation ages and sizes for two site qualities for paper birch for boltwood and sawtimber, for other hardwoods for sawtimber, for spruce-fir for pulpwood, and for spruce for sawtimber. The expected rotations for paper birch are: boltwood with an average stand diameter of 9 inches on site 70, 45 years; boltwood with an 8-inch average stand diameter on site 50, 65 years; sawtimber on site 70, 65 years; and sawtimber on site 50, 75 years. The rotation age in managed stands for hardwood sawtimber of other species has been estimated as 120 years for site 70, and 135 years for site 50. For spruce-fir pulpwood the estimated rotation for average 9-inch diameter wood is 65 years for site 70 and 75 years for 8-inch average stand diameter on site 50. For spruce sawtimber, the rotation ages are estimated at 120 years for site 70 and 135 years for site 60.

THE POSSIBILITIES FOR INTENSIVE SHORT-ROTATION FORESTRY

I predict that by 1980 our present long-rotation, chain-saw forestry will have begun to give way to intensive short-rotation forestry. And this could be started on our best sites with densely stocked young stands.

Although we do not have the large expanses of flat or rolling forest land most suitable for the use of heavy machinery, our climate and most of our soils are conducive to maximum wood production under intensive culture with the elimination of practically all hand labor. Heavy equipment is already available for intensive silviculture, including site preparation, planting, cultivation, thinning, and harvesting.

Hayes (*1970*) has reported the cost range for site preparation —including clearing, debris treatment, soil preparation, and planting—as from $25 to $45 per acre. He concludes that, "A new technological breakthrough is long overdue. We have tried to beat trees to death, poison them, chew them up, and drive them into the ground; but we usually revert to overpowering them."

The economical establishment of densely stocked conifers and hardwoods that cannot now be propagated from cuttings will require direct-seeding. A furrow-seeder is available that can direct-seed an acre of white or red pine, in furrows spaced 12 feet apart, in approximately 15 minutes on an open field with a 0- to 8-percent slope; and in approximately 32 minutes on a brushy hillside with a 10- to 20-percent slope (*Graber and Thompson 1969*).

An efficient machine for planting dormant hardwood cuttings has been developed and used in the nursery at Indian Head, Saskatchewan. A four-row machine can plant 30,000 cuttings per hour with a crew of ten. This includes the labor for transporting the cuttings to the field and replenishing the cutting boxes on the planter (*Cram 1969*).

A mechanized harvesting-thinning machine has been designed to mechanically harvest undersized timber in overstocked natural stands and in plantations. The smaller timber could not be harvested manually because of excessive cost, but this new machine

is said to be turning this operation into a profit-maker (*Anon. 1968*).

Machine thinning will require mechanical (line or row) thinning rather than selective silvicultural thinning. Shortage of labor for forest management in Poland has led to research on machine thinnings. Bernadski (*1969*) has reported that line thinning, when compared with selection thinning, has resulted in reducing the number of the most valuable trees and has decreased the possibility for selection of plus trees. However, the negative impact of this thinning is more strongly marked in stands of poor quality than in stands of high quality growing at dense spacing.

MINI-ROTATION FORESTRY, THE FIFTH FOREST OF THE NORTHEAST

According to Wheeler (*1960*), "Even now the Third Forest of the South is beginning to materialize. Over 15 million acres—an area about the combined size of New Hampshire, Connecticut, Delaware, and Maryland—have been planted in pines."

How soon can we start to obtain the practical know-how needed to establish our Fifth Forest of the Northeast for mini-rotation forestry on the more productive and accessible lands, and in young, fully stocked natural stands that are available for fiber and timber production? We should have started at least 20 years ago. The eventually irresistible pressure of public opinion and limited land and woods labor will become effective much sooner than the selection and creation of genetically superior fast-growing trees and the development of establishment and cultural methods needed for maximum forest production on mini-rotations.

I am suggesting the term "mini-rotation forestry" to include the production of fiber, on rotations of 2 to 4 or 5 years (mini-rotation fiber production);[1] boltwood for fiber, particle board, or other uses on rotations of 6 to 15 years (mini-rotation boltwood production); and lumber and veneer logs on rotations of 15 to 30 years (mini-rotation timber production). Depending on the

[1] The utilization of juvenile growth of sycamore for fiber has been called "silage" sycamore by McAlpine *et al.* (*1966*).

species and the product, mini-rotations (like mini-skirts) may be of various lengths, but always short for the particular objective.

One or several species, varieties, or hybrids may be grown in mixture for one, two, or all three mini-rotations (fiber, boltwood, or timber).

Mini-rotation forestry will require: (1) machine site preparation, planting, cultivation, and harvesting; (2) intensive culture, including fertilization on good sites; (3) fast-growing superior varieties or hybrids; and (4) utilization of small stem-wood, and if possible, branch-wood.

The advantages of mini-rotation forestry will be: (1) early amortization of the cost of site preparation, planting, and early culture; (2) very much smaller land areas for the production of large quantities of fiber or timber; (3) profitable use of the most highly productive and economically manageable lands; and (4) smaller and cleaner clearcut area that are less likely to be objectionable to the general public.

Mini-rotation forestry must be based on even-aged culture.

I am fully aware of the possible public objection to clearcutting, but there never has been any public outcry against the use of large open areas for extensive pasture or agricultural crop production. The main reason for public objection to clearcutting of forest stands may be the extent of such areas and the scraggly appearance of the nonmerchantable residual trees and the large amount of slash and debris left after logging, which aesthetically can be as objectionable as an automobile junk yard.

The utilization of the best productive timber sites for mini-rotation forestry will minimize the area of clearcutting; the less productive parts of forest properties should be left in long-rotation management. The need for intensive culture to maximize wood production on mini-rotations will profit most from complete disposal of slash by chipping all such material, either for commercial utilization or to provide a mulch that can be worked into the soil in fitting the land for the succeeding crop. With such utilization, site preparation at the end of the longest mini-rotation would leave the land with the same appearance as well-kept farm land.

Maximum production of usable material under mini-rotation management will require complete utilization of the site. This will necessitate close planting (the spacing depending on the species or variety and on the length of the longest and/or shortest rotation objective), with frequent thinnings to maintain the growth rate of the remaining stand. Each required thinning must provide a merchantable yield of fiber or boltwood.

Much of the land required for mini-rotation forestry would presently be classified as farmland, either actively farmed or abandoned. There is every indication that the availability of such land for forestry will increase in future years; extensive farming will be profitable on only a relatively small proportion of the land area in the Northeast. Considerable abandoned farmland in private ownership would probably be available for lease by wood-using industries interested in mini-rotation management. The owners themselves would not be in a position to manage for wood production, but either wood-using industries or forest-production companies with sufficient equipment could manage many of these smaller properties for mini-rotation production.

SPECIES AND HYBRIDS FOR MINI-ROTATION TRIALS

The following species and hybrids could be used immediately for small-scale trials of mini-rotation management in the Northeast:

Hardwoods:

Poplar (*Populus*) hybrids
Eastern cottonwood (*Populus deltoides* Bartr.)
Silver maple (*Acer saccharinum* L.)
Quaking aspen (*Populus tremuloides* Michx.)
Bigtooth aspen (*Populus grandidentata* Michx.)
American sycamore (*Platanus occidentalis* L.)
White birch (*Betula papyrifera* Marsh.)
Yellow birch (*Betula alleghaniensis* Britton)
Northern red oak (*Quercus rubra* L.)
Black cherry (*Prunus serotina* Ehrh.)
Black willow (*Salix nigra* Marsh.)
Red maple (*Acer rubrum* L.)
European black alder [*Alnus glutinosa* (L.) Gaertn.]

Pin cherry (*Prunus pensylvanica* L.)
Gray birch (*Betula populifolia* Marsh.)
Tree of heaven [*Ailanthus altissima* (Mill.) Swingle]

Conifers:

Eastern white pine (*Pinus strobus* L.)
Hybrid larch (*Larix* × *eurolepis* Henry)
Japanese larch (*Larix leptolepis* Sieb. & Zucc.)
Norway spruce [*Picea abies* (L.) Karst.]
White spruce [*Picea glauca* (Moench) Voss]
Balsam fir [*Abies balsamea* (L.) Mill.]
Scotch pine (*Pinus sylvestris* L.)
Red pine (*Pinus resinosa* Ait.)
Jack pine (*Pinus banksiana* Lamb)
Japanese red pine (*Pinus densiflora* Sieb. and Zucc.)

Some of the species listed above will be suitable only for mini-rotation fiber production (gray birch, pin cherry), others may be used for all three mini-rotations (hybrid poplars, cottonwood, sycamore, white pine, larch). Nonsprouting species, such as the conifers, would require replanting after each harvest cutting. The possibilities of a few of these species will be indicated briefly. The hybrid poplars will be used to present a prototype for mini-rotation management.

Eastern cottonwood. — Superior genotypes of this species will grow as rapidly on the most fertile bottomland sites in the Northeast as cottonwoods do on the highly fertile soils of the batture lands of the Mississippi (figs. 1 and 2).

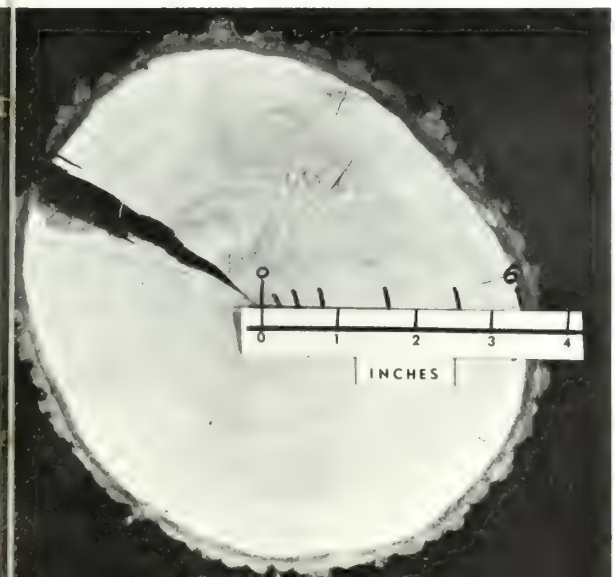


Figure 1.—A d.b.h. (diameter breast high) section from a native eastern cottonwood growing on a bottomland site near Albany, New York. This 6-year-old tree was 6.75 inches in d.b.h. inside bark (i.b.).

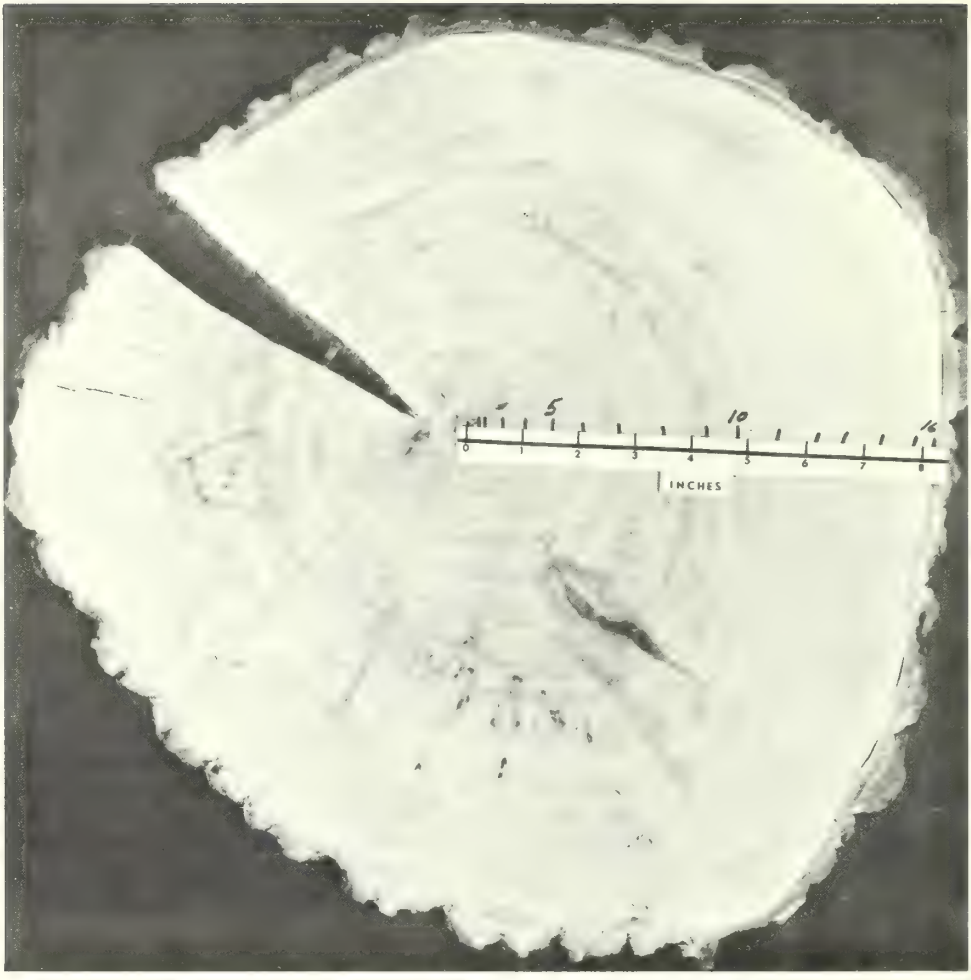
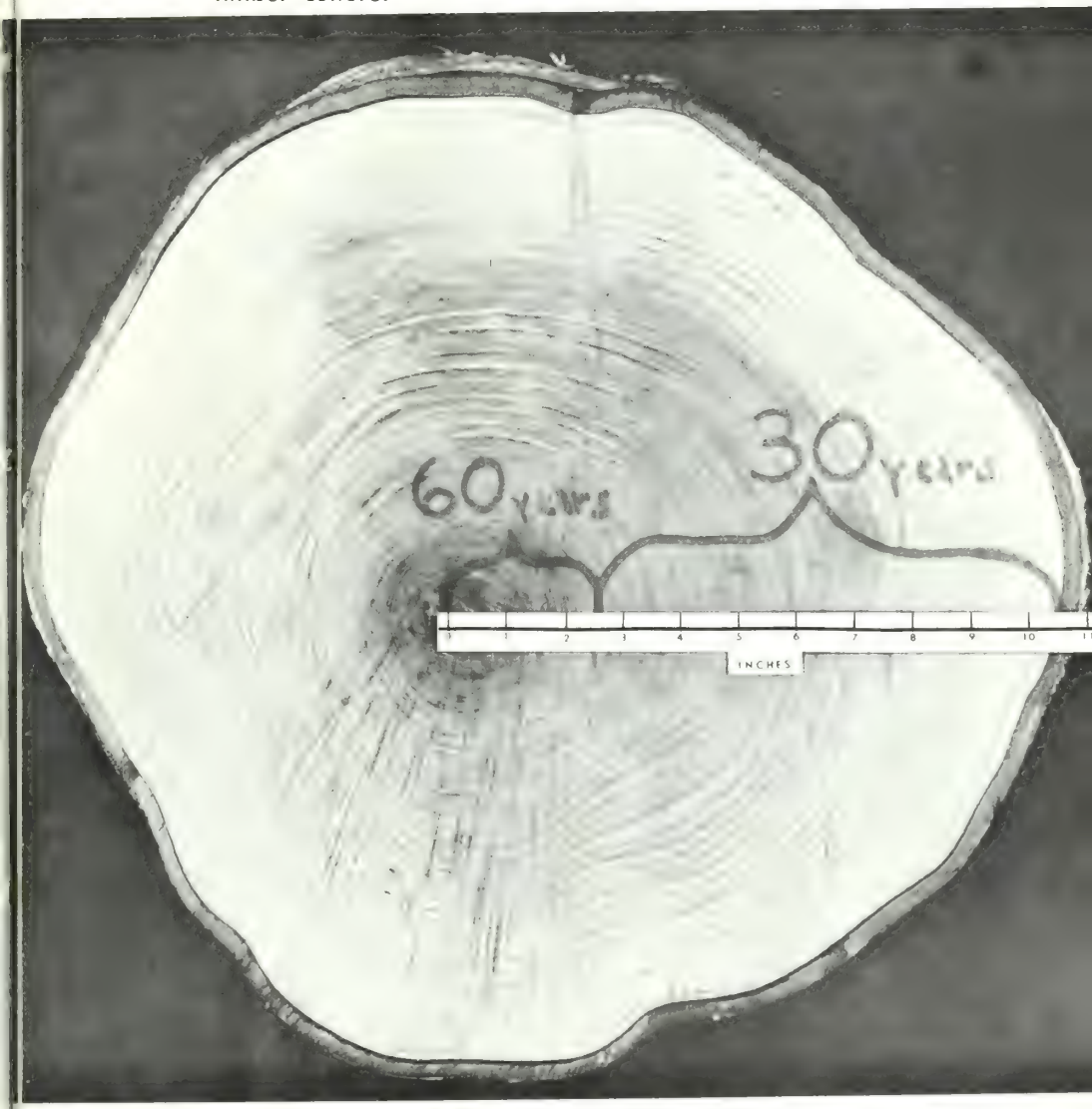


Figure 2.—A d.b.h. section from a 16-year-old eastern cottonwood from a bottomland site in the vicinity of Albany, New York; d.b.h. (i.b.) was 16.5 inches.

Yellow birch. — The growth possibilities of yellow birch are indicated in figure 3. During 60 years of suppression this tree grew approximately 5 inches in diameter at 18 inches above the ground. During the 30 years after release, it demonstrated a diameter growth potential of approximately 0.5 inch per year. This growth rate would be sufficient for mini-rotation timber production in 30 years.

Figure 3.—A yellow birch section taken 18 inches above the ground from a tree cut near Berlin, New Hampshire, 16 inches (i.b.). The total age is 90 years, but the tree was obviously suppressed during the first 60 years. In the last 30 years the tree has grown at a rate that indicates excellent possibilities for selection of genetically fast-growing trees for intensive mini-rotation timber culture.



Silver maple. — H. C. Larsson, of the Ontario Department of Lands and Forests, has been selecting plus trees of this species. Figures 4 and 5 show plus-tree selections in a stand that originated after clearcutting in 1926 (apparently largely from sprout reproduction). Note the gross volume available after approximately 36 years.

Figure 4.—Silver maple selection B-3-6; d.b.h. 12.2 inches; total height 90 feet; stand age approximately 36 years. (Ontario Dep. of Lands and Forests Photo.)

Figure 5.—Silver maple selection B-3-4; d.b.h. 11.0 inches; total height 75 feet; approximate stand age 36 years. (Ontario Dep. of Lands and Forests Photo.)

Hybrid larch. — The case for hybrid larch has been presented by Perry and Cook (*1965*), and by Cook (*1969*). The growth rates of five plus trees of the Dunkeld hybrid larch are listed in the following tabulation (*from Cook 1969*):

Name or number	*Years planted*	*D.b.h. (inches)*	*Height (feet)*
4752	3	—	10
4454	6	—	21
4131	11	5.6	32
Bedgebury Giant	12	6.4	40
Giant in No. 19	30	14.4	76
Giant in No. 7	30	16.0	75

Figures 6 and 7 illustrate the growth in Cooxrox Forest, Stephentown, New York.

Figure 6.—The "Giant in number 19", probably an F_3 hybrid. This stand was planted with 2-0 seedlings in November 1935. The photograph was taken after 30 growing seasons when the Giant was 14.4 inches d.b.h. and 76 feet tall. (D. B. Cook Photo.)

Figure 7.—The "Giant in number 7" was planted as a 2-0 seedling in a single-tree failed spot in a red pine plantation that was established in 1931. After 30 growing seasons, this larch, although 5 years younger than the red pines, was 16.0 inches in diameter and 75 feet in total height—considerably taller than even the best of the red pines. (D. B. Cook Photo.)

Eastern white pine. — The excellent possibilities for mini-rotation management of eastern white pine are apparent in the reported yields of plantations in Pennsylvania (table 3). The first profitable cuttings on the basis of present pulpwood specifications would probably be at 20 years on site index 90 with a *merchantable volume* of 8.5 cords, and on site index 70 at 25 years with 10.4 cords.

With utilization of the *total volume* (small-diameter stemwood), site index 70 would yield 12 cords at 15 years, 23.4 cords at 20 years, and 35.9 cords at 25 years. Site index 90 would yield 14.8 cords at 15 years, 31 cords at 20 years, and 48 cords at 25 years. I believe that all these figures are minimums, that they could be increased by at least 50 percent, and that the earliest yields probably could be doubled by the use of inherently fast-

Table 3.—Eastern white pine. Empirical yield table for 4- x 4-foot plantations in Pennsylvania [1]

Stand age from planting (years)	50-year site index: 70					50-year site index: 90				
	Trees[2]	Avg. d.b.h.	Volume			Trees[2]	Avg. d.b.h.	Volume		
			Total	Merchantable	Total			Total	Merchantable	Total
	No.	*In.*	*Cu. ft.*[3]	*Cords*[4]	*Cords*[5]	*No.*	*In.*	*Cu. ft.*[3]	*Cords*[4]	*Cords*[5]
15	1,386	3.3	1,076	0.2	12.0	1,098	4.2	1,332	1.9	14.8
20	1,543	4.2	2,110	3.6	23.4	1,156	5.1	2,787	8.5	31.0
25	1,324	5.0	3,231	10.4	35.9	992	6.0	4,322	19.5	48.0
30	1,104	5.7	4,399	19.5	48.9	793	6.9	5,890	33.5	65.4
35	900	6.4	5,553	30.0	61.7	624	7.9	7,435	50.6	82.6
40	729	7.2	6,655	40.1	73.9	474	9.2	8,894	64.1	98.8
45	594	8.0	7,654	48.6	85.0	349	10.7	10,236	74.5	113.7
50	489	8.8	8,505	56.0	94.5	262	12.3	11,375	83.4	126.4
55	412	9.6	9,224	62.7	102.5	203	14.1	12,327	91.3	137.0

[1] Excerpt from Marty (*1965, pp. 53,54*). Source data: Delong, Thomas S. (*1955*).
[2] All trees 1.0 inch + d.b.h.
[3] Total cubic-foot volume including stump, stem, and bark, but not limbwood.
[4] Rough cords to a variable top of not less than 4.0 inches inside bark, and a 1-foot stump.
[5] Total cubic-foot volume converted, for this paper, on the basis of 90 cubic feet per cord.

growing trees, closer spacing, adequate site preparation, fertilization, and early cultivation on the better sites available in the Northeast (fig. 8).

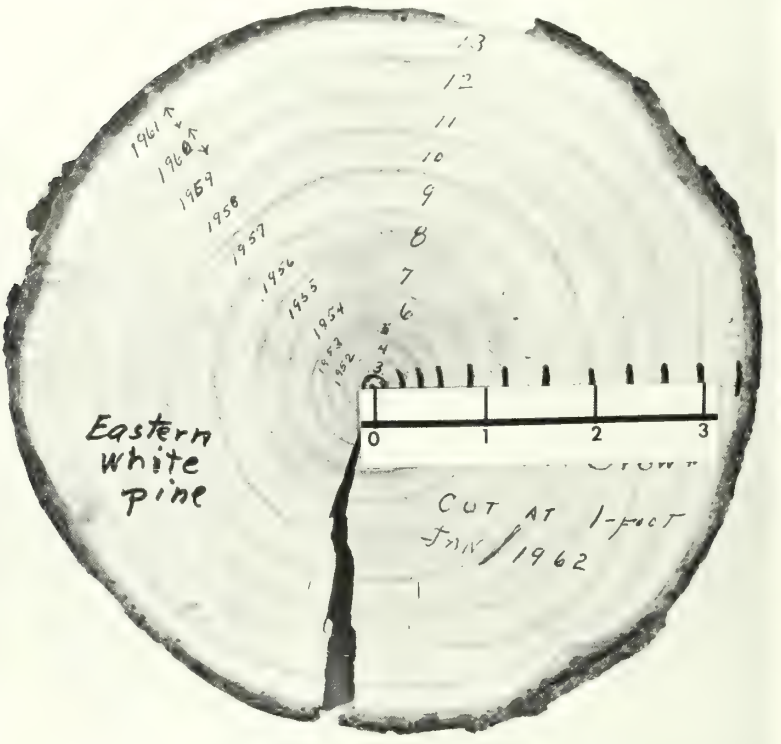


Figure 8.—A section of eastern white pine, cut 1 foot above the ground, to illustrate early growth without plantation culture. Age 13 years, diameter 6.5 inches (i.b.).

White spruce. — Fiber production in 6 to 8 years, boltwood production in 12 to 15 years, and timber production in 30 years will be possible with improved varieties of white spruce under intensive mini-rotation management. The growth possibilities of this species are shown in figures 9 and 10.

Figure 9.—A cross-section of white spruce 20 inches in diameter (i.b.) taken at 1-foot stump height. This tree, from Colebrook, New Hampshire, was 43 years old at the stump, 17 inches in d.b.h. (o.b.), and 58 feet in total height.

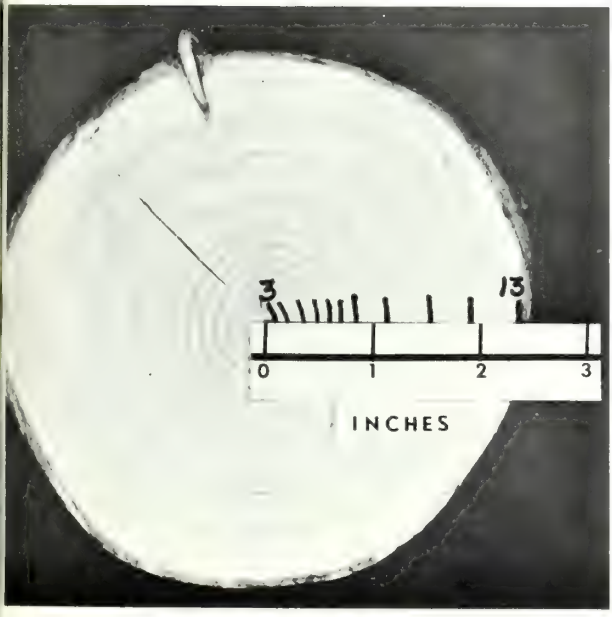


Figure 10.—A cross-section, 24 inches above the ground, of a pedigreed white spruce seedling planted in sod at Williamstown, Massachusetts. The tree was 13 years old from seed; diameter of this section 4.75 inches (i.b.). Note the rapid growth from the 9th to 13th year. Early cultivation and fertilization would have greatly increased the growth rate during the first 9 years.

Norway spruce. — This species has been planted in the Northeast since Colonial days. It usually outgrows white spruce in its early years. Hughes (*1970*) has reported that the mean annual net increment of a 51-year-old stand in Nova Scotia was 144 merchantable cubic feet per acre, and that this level of production (1.7 cords per acre per year) is almost twice the peak increment shown for site quality 1 in Nova Scotia. Figure 11 indicates the possibilities for rapid juvenile growth of this species.

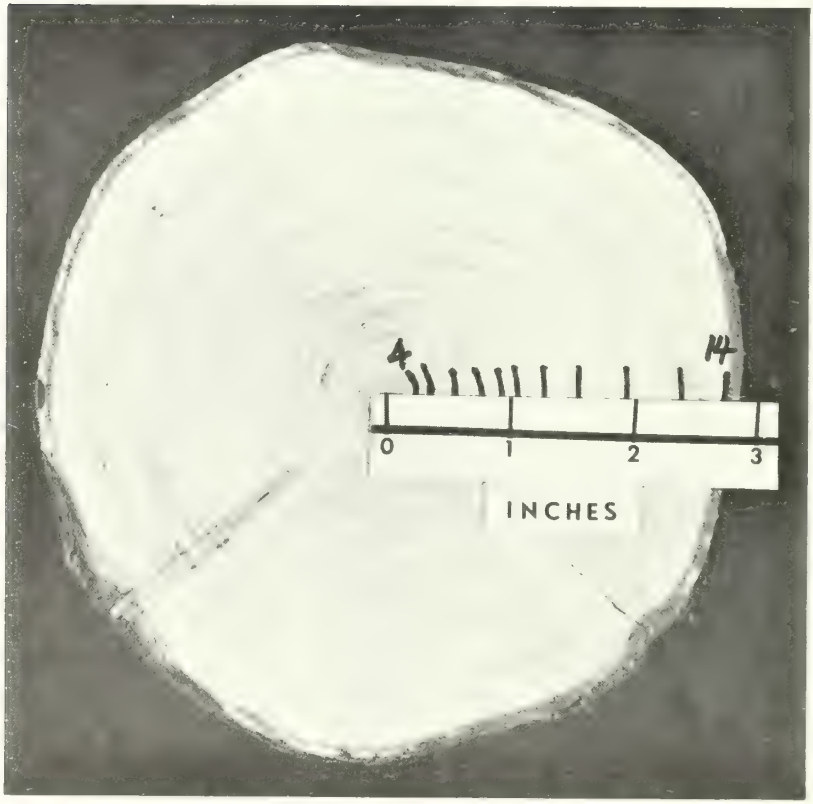


Figure 11.—Norway spruce. A cross-section taken 2 feet above the ground, 5.5 inches in diameter (i.b.). The tree, 14 years old from seed, was planted in sod without cultivation at Williamstown, Massachusetts. Note the improved growth from the 9th to 14th year. Selection for rapid inherent growth, site preparation, and cultivation undoubtedly would have doubled the earlier growth rate.

Scotch pine. — The total volume produced in 18 years by the two best seedlots in a provenance test planted at 8- x 8-foot spacing was 947 and 973 cubic feet per acre, approximately 10 cords (*Schreiner et al. 1962*). This volume could be more than doubled with site preparation, closer spacing, and cultivation. Pedigreed seedlings have grown 9 inches or more in d.b.h. (i.b.) in 15 years from seed without site preparation or cultivation at Williamstown, Massachusetts (fig. 12).

Figure 12.—Scotch pine. A section taken 2 feet above the ground of a Scotch pine 15 years from seed without site preparation or cultivation at Williamstown, Massachusetts, diameter (i.b.) 9.5 inches.

Red pine. — This species should be considered for mini-rotation fiber and boltwood management, particularly on marginal sites. The possibilities for rapid early growth are illustrated in figure 13. Intensive culture of this plantation in Alfred, Maine, would have increased early growth and maintained the growth rate through the last 5 years.

Figure 13.—A red pine plantation tree at Alfred, Maine. The section was cut 1 foot above the ground. Age 19 years, diameter 10.2 inches (i.b.).

Hybrid poplars. — Some 250 of the more than 13,000 hybrid poplars produced in 1925 and 1926 by the Cooperative Oxford Paper Company—New York Botanical Garden Hybridization Project (*Stout and Schreiner 1933; Schreiner 1937*) have been selected and tested by the Northeastern Forest Experiment Station for their performance on upland sites in the Northeast. The growth potential of some of the best hybrids is apparent in figures 14 to 19.

Figures 14 and 15 show one of the hybrids — NE-200 (*P. deltoides* × *P. trichocarpa*)—that were selected in the original Oxford Paper Company plantation at Frye, Maine, for clonal tests and were cut for pulping tests. These original hybrid seedlings were planted at 6- x 6-foot spacing and were never thinned. Figure 15 shows the merchantable pulpwood from this tree.

Figure 14.—Poplar hybrid NE-200 (*P. deltoides* × *P. trichocarpa*) selected for clonal and pulping tests. Age 18 years; d.b.h. 11.5 inches; total height 60 feet.

Figure 15.—This merchantable pulpwood was cut from the tree shown in figure 14.

The difference in growth of the same hybrid clone, the Androscoggin poplar (*Schreiner and Stout 1934*), in the open and at 6- x 6-foot plantation spacing is shown in figures 16 and 17. The open-grown tree in Philadelphia (fig. 16) was 30 inches in d.b.h. and 80 feet tall at 16 years. The ramets of this clone in the 6 x 6 plantation near Frye, Maine (fig. 17) averaged 8 inches in d.b.h. and approximately 60 feet in total height at 15 years. But the total cubic volume per acre was practically the same for the 6- x 6-foot plantation as for the open-grown individual at an estimated spacing of 25 x 25 feet.

Figure 16.—Hybrid poplar. An open-grown specimen of the Androscoggin poplar growing on fertile bottomland soil in Philadelphia. At 16 years this tree was 30 inches in d.b.h. (o.b.) and 80 feet tall. This same hybrid clone was planted at 6- x 6-foot spacing near Frye, Maine (fig. 17).

Figure 17.—Hybrid poplar. Ramets of the Androscoggin poplar planted in a 6- x 6-foot plantation on fertile bottomland near Frye, Maine. The trees were 15 years old, their average d.b.h. was 8 inches, and their average total height was 60 feet (see also fig. 16).

Figure 18.—Hybrid poplar. This is a section (18 inches above the ground) from a 20-year-old tree in a test plantation established with dormant cuttings at 4- by 4-foot spacing, on a plowed and harrowed upland site at Williamstown, Massachusetts. The test plantation was cultivated during the first year only, and thinned lightly as needed.

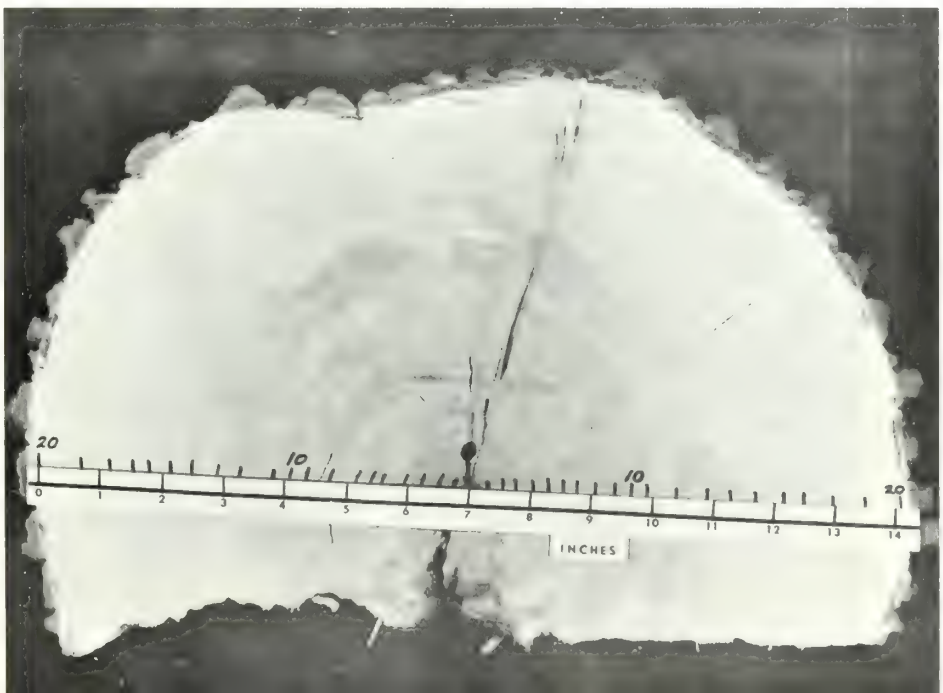


Figure 19.—Hybrid poplar clone NE-264 (*P.* cv. Angulata x *P.* cv. Volga) in a clonal test on an upland site in Williamstown, Massachusetts. This photo was taken when the trees were 20 years old. Fifteen-year average height was 61 feet; maximum height 76 feet. (Photo by John Kendig.)

MINI-ROTATION HYBRID POPLAR FIBER PRODUCTION

In the spring of 1935, 4-year-old nursery stock of 15 hybrid poplar clones in the Oxford Paper Company's nursery near Frye, Maine, were cut back to the ground to produce cutting stock for use in the spring of 1936. These hybrids had been grown from unrooted cuttings at 1-foot spacing in rows spaced 4 feet apart. Since this was an opportunity to determine the production of fiber on a short rotation, I stored the 4-year-old stems for dry-weight determination and possible pulping trials. The length of the row from which each lot of stems was taken and the percent survival in the row were recorded when the hybrids were cut.

Survival within the hybrid clones varied from 70 percent to more than 95 percent. Observations on the various hybrids indicated that the growth of trees spaced 1 foot apart (100-percent

survival) was fully as good as the growth in more sparsely populated portions of the same clones. Therefore, for comparison of the hybrids, the yield per acre of peeled stems was calculated on the basis of 95-percent survival.

The oven-dry weight of the branches with bark, and of the oven-dry weight of peeled stems exclusive of the leader (the fourth-year leader was not included) was determined in August 1935. The calculated yields per acre of side branches with bark, of peeled stem-wood and the equivalent in cords of peeled stem-wood, are given in table 4. The range in oven-dry weight of the peeled stem-wood of these 15 clones varied from 17,240 pounds (8.2 cords per acre) to 4,680 pounds (2.2 cords per acre). An examination of the growth rings indicated that the optimum rotation for

Table 4.—Yields of fifteen 4-year-old hybrid poplar clones at 1- x 4-foot spacing

[Oxford Paper Company Nursery, Frye, Maine, 1935]

Hybrid No.	Oven-dry yield estimated on basis of 95-percent survival		
	Branches with bark	Peeled stem-wood[1]	
	Pounds per acre	*Pounds per acre*	*Cords per acre*[2]
NE-44	5,920	17,240	8.2
-41	5,480	15,320	7.3
-49	2,440	14,300	6.8
-4	5,340	13,800	6.6
-50	4,460	13,560	6.5
-39	6,800	13,560	6.5
-46	6,320	13,480	6.4
-28	5,400	13,240	6.3
-29	4,560	11,680	5.6
-45	4,280	10,980	5.2
-32	3,600	10,900	5.2
-21	3,300	10,820	5.2
-54	5,200	8,100	3.9
-9	5,440	7,760	3.7
-26	1,760	4,680	2.2

[1] Oven-dry weight of peeled 3-year stems; the fourth-year leader was not included.
[2] Based on 2,100 pounds per cord, the reported oven-dry weight of aspen.

this spacing and this site in western Maine would be 3 rather than 4 years. Diameter growth was maintained during the third year, but it dropped considerably during the fourth year.

These early results in Maine indicated the possibilities of very short rotations for the production of poplar fiber, but unfortunately this 1935 research was at least 35 years ahead of its time. The pulp and paper management people agreed:

- That the production of fiber from fast-growing hybrid poplars on a 2- to 3-year rotation offered excellent possibilities in terms of the amount of fiber produced per acre.
- That a machine to economically harvest such small stems could be developed.
- That once the stand was planted, it would reproduce from sprouts after each fiber harvest.
- Cultivation to control weeds would be necessary only once or twice in the first year after each harvest.

But there was, at that time, one insurmountable obstacle to such short-rotation fiber production—the separation of the bark from the chips or pulp. And for the paper maker, this problem is still with us. Fortunately, there now is sufficient interest in separating bark from chips to predict that practical methods will be developed within the next decade.

Erickson (*1970*) has posed two questions that may bear on this problem within the next 10 years: "Will the technology in pulping change so that more bark will be allowed? Will it be feasible in the future to remove most of the bark during the pulping process?"

Present research on separation of bark after chipping has involved the bark of larger trees. I suggest that the young bark of 1-, 2-, or 3-year-old stems and branches may not be as troublesome as the mature bark of older trees; that it might be an allowable constituent of the pulp if we can persuade the pulp and paper researchers to seriously — *and strenuously* — attack this problem.

The utilization of such young wood may also involve shorter fiber. However, there is evidence that genetic selection for reason-

ably long-fibered young growth is possible. It is also reasonable to suggest that for many uses, even in paper stock, short fibers will prove suitable. This should apply, for example, to the use of short-fibered hardwoods for opacity and printability of high-grade papers.

Bowersox and Ward (*1968*) are investigating the juvenile growth and yield in Pennsylvania of the Northeastern Station's hybrid poplar clone NE-388 (*P. maximowiczii* × *P. trichocarpa*). The yields per acre at three different spacings are reported in table 5 and illustrated in figures 20 and 21. The rate of increase (ta-

Table 5.—Yields of oven-dry peeled stem-wood; hybrid poplar clone NE-388

[State College, Pennsylvania]

Spacing (feet)	1-year-old[1] trees		2-year-old[1] trees		3-year-old[2] trees	
	Pounds per acre	*Cords per acre*[3]	*Pounds per acre*	*Cords per acre*[3]	*Pounds per acre*	*Cords per acre*[3]
½ x 2	1,024	0.5	3,816	1.8	11,940	5.7
1 x 2	658	.3	3,101	1.5	10,006	4.8
2 x 2	455	.2	1,923	.9	7,616	3.6

[1] Excerpt from Bowersox and Ward (*1968*).
[2] Todd W. Bowersox, personal communication.
[3] Converted for this paper on the basis of 2,100 pounds per cord, the reported oven-dry weight of aspen.

Figure 20.—Hybrid poplar NE-388 (*P. maximowiczii* × *P. trichocarpa*). This is a 3-year-old stand from dormant cuttings. (Pa. State Univ. Agr. Exp. Sta. Photo.)

Figure 21.—Hybrid poplar NE-388 (*P. maximowiczii* × *P. trichocarpa*). Interior of the 2- x 2-foot, 3-year-old planting. (Pa. State Univ. Agr. Exp. Sta. Photo.)

ble 5) indicates that this hybrid will equal or surpass the 4-year yield of clone NE-44 in the 1935 tests in Maine.

A final word on the possibilities of mini-rotation of hybrid poplar for fiber production. The yields in Maine and those in Pennsylvania were based on 4- and 3-year-old trees from unrooted cuttings; the plants had not been cut back to the ground (stooled).

The 4-year-old clones in the Maine trials ranged from 8 to 18 feet in average height. If these hybrids had been stooled, they would have grown to the same heights in not more than 2 or 3 years. Stooled hybrids have grown to average heights of 10 to 14 feet in 1 year in nursery plantings in Philadelphia (fig. 22).

Figure 22.—Hybrid poplar nursery stools at 1- x 4-foot spacing, Philadelphia, Pa. This shows 1-year growth on 3-year-old stools that had been cut back annually for the production of cuttings.

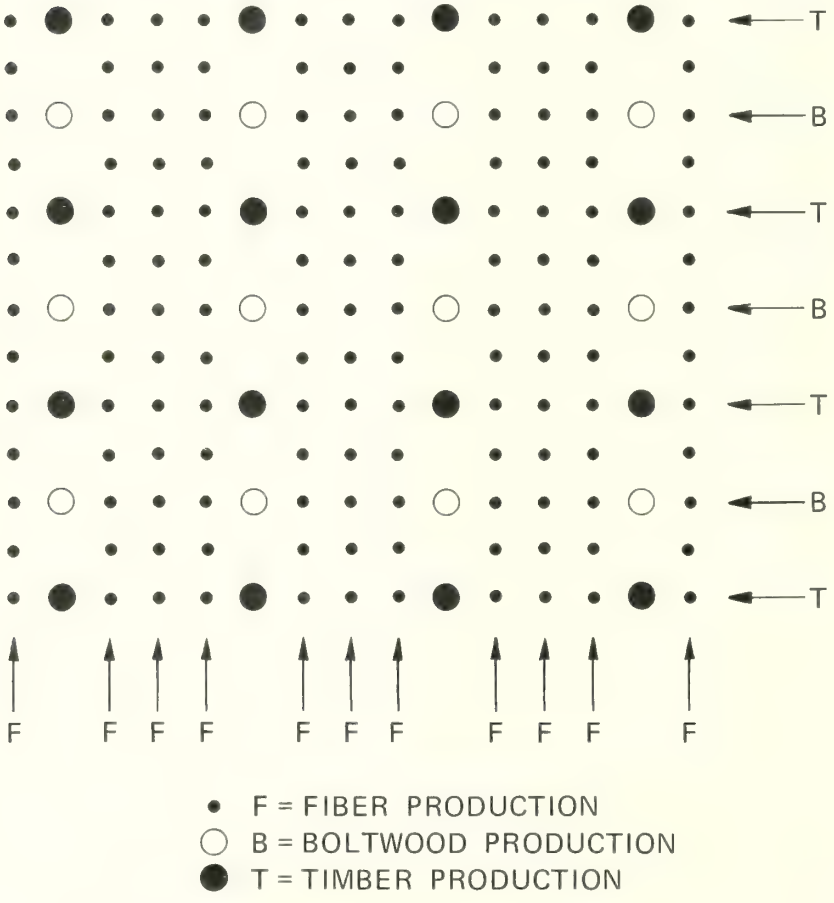
MINI-ROTATION HYBRID POPLAR BOLTWOOD AND TIMBER PRODUCTION

Hybrid poplars planted at 6- x 6-foot spacing on good upland sites would yield 10 cords per acre of boltwood from thinnings between the 8th and 10th years, and a final harvest of 30 cords per acre at 15 years (*Schreiner 1949*). With 4- x 4-foot spacing, two thinnings (one at 5 to 8 years and a second at 12 to 15 years) would produce considerable additional boltwood and would leave about 170 trees per acre spaced 16 x 16 feet for a final cordwood or timber and veener-wood harvest between the 20th and the 25th years.

MINI-ROTATION FIBER, BOLTWOOD, AND TIMBER PRODUCTION WITH A SINGLE SPECIES OR WITH TWO OR THREE SPECIES

Figure 23 shows a generalized layout without designation of species or spacings. This could be for a single species. But for non-sprouting species, such as conifers, there would be only one fiber harvest; it would not pay to reseed the fiber (F) rows. For a sprouting species, the fiber harvests could be repeated at the most profitable intervals.

Figure 23.—A generalized layout for a mini-rotation plantation for producing fiber, boltwood, and timber.



A combination of species would be preferable: for example, hybrid poplar for fiber (F) with white pine for boltwood (B) and timber (T); or with larch for the boltwood (B) and white pine for the timber (T) mini-rotations.

Recommendations on choice of species, species mixtures, and spacing must await the results of small-scale applied research. I sincerely hope that such applied research will be started in the near future.

In closing, I will again quote Fedkiw: "There has never been a greater need for enlightened leadership and exploding innovations in forest practice."

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THE FOREST SERVICE of the U. S. Department of Agriculture is dedicated to the principle of multiple use management of the Nation's forest resources for sustained yields of wood, water, forage, wildlife, and recreation. Through forestry research, cooperation with the States and private forest owners, and management of the National Forests and National Grasslands, it strives — as directed by Congress — to provide increasingly greater service to a growing Nation.

A Sugar Maple
PLANTING STUDY
in Vermont

by Harry W. Yawney
and Clayton M. Carl, Jr.

U.S.D.A. FOREST SERVICE RESEARCH PAPER NE-175
1970

NORTHEASTERN FOREST EXPERIMENT STATION, UPPER DARBY, PA.
FOREST SERVICE, U.S. DEPARTMENT OF AGRICULTURE
RICHARD D. LANE, DIRECTOR

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A Sugar Maple Planting Study in Vermont

PAST ATTEMPTS to establish sugar maple (*Acer saccharum* Marsh.) by planting have generally met with little success. The failures have been blamed mainly on competition by other vegetation and on damage done by animals.

Finding an effective way to establish sugar maple seedlings is a key part in the research being carried on in Vermont by the USDA Forest Service to develop superior sugar maples for producing sap and sugar.

In 1964 we began a small planting study with sugar maple seedling to evaluate several methods of weed control and protection from animals. The results indicated that black plastic film used as mulch provides excellent weed control for as long as 4 years, and increases growth significantly. However, the protective treatments we tried (an animal repellent and wire screens) were not entirely effective; so the full potential of the black plastic mulch treatment was masked by damage done by repeated deer browsing.

BACKGROUND

Sensitivity of hardwood seedlings to competition from weeds and grasses has been reported by many investigators *(Schreiner 1945; Rudolph 1950; Merz and Finn 1955; Pruett and Gatherum 1961; Byrnes 1966;* and *Bjorkbom 1968).* Seedling survival and growth are adversely influenced in several ways. The most obvious are the effects of competition for light, moisture, and nutrients. Other effects include mechanical damage resulting from snow mashing down overtopping herbaceous cover, and dense stands of weeds and grasses that provide ideal habitat for mice and rabbits.

Animal damage has been reported to be a great hazard to the success of hardwood plantings. In a survey of hardwood plantations in the Lake States, which included sugar maple, Stoeckeler and Limstrom *(1950)* found that over 80 percent of the seedlings were damaged by deer browsing. Wallihan *(1959)* summarized his analysis of northern hardwood plantations in New York by stating that the risk of serious animal damage was so great that he questioned the feasibility of continuing hardwood planting without some effective means of control.

The literature leaves little doubt that control of competing vegetation and animal damage are essential. The questions that arise are: What degree of control is required? And what are the best methods of achieving it?

METHODS & MATERIALS

The planting site selected for our study was an abandoned highland pasture, located on the Rochester Ranger District of the Green Mountain National Forest in northern Vermont. This site is situated on a 10-percent east slope at an elevation of 1,800 feet. The soil is a Calis loam — a deep, moderately well drained soil of glacial till origin.

Three weed-control treatments and three protective measures were tested. These were designed to provide a wide range of conditions, as follows:

Weed-Control Treatments

1. Control.—Planting in sod.
2. Cultivation.—Plots were prepared by plowing and disking before planting to provide a temporary relief from competing herbaceous vegetation.
3. Cultivation plus black plastic film as mulch.—Plots were prepared as in treatment 2, followed by placement of black polyethylene film (4 mils thick and 3 feet wide) over the entire plot after planting. The purpose of this treatment was to provide weed control for several years.

Protective Treatments

1. Control.—No protection.
2. Repellent.—Temporary protection was provided by dipping the seedling before planting in a commercial repellent known as Z.I.P. (active ingredients 30 percent zinc dithiocarbamate-amine complex and 10 percent polyethylene polysulfide as sticker).
3. Wire screens.—Initially, complete protection was provided by enclosing the seedlings in cylindrical 8-inch, 30-inch high screens of $\frac{1}{4}$-inch hardware cloth.

The study was designed as a split-plot experiment. Five blocks were used, each comprising three plots, each of which contained 48 seedlings (16 per subtreatment)—a total of 144 seedlings per block. The main plot treatments were weed control. Within each main plot, protection treatments were assigned at random to individual seedlings to intermix the protective treatments throughout each main plot.

Planting was done early in November 1964. The planting stock was 2-0 seedlings that ranged in height from 12 to 30 inches and average 21 inches. Seedlings were carefully hand-planted in prepared holes on a 3-x-3-foot spacing in 6 rows of 8 seedlings per row (fig. 1).

Final measurements were made early in the spring of 1969. Data were recorded on survival, stem height, stem diameter at 1 inch above the root collar, and green weight of stems clipped

Figure 1.—A study plot mulched with black plastic film. The wire screens were designed to protect the seedlings from animals.

at $\frac{1}{2}$ inch above the root collar. Plot means were based on survivors; and the data were analyzed by analysis of variance for split plots.

Survival

Initial spring survival of the fall-planted 2-0 seedlings was found to be extremely good. Seedling losses amounted to only 2.5 percent (18 of the 720 planted).

At the end of four growing seasons, overall survival for all treatments was 91.5 percent (table 1). Statistically there were no differences in survival due to the weed-control treatments, but significant differences did occur as a result of the protective treatments. However, the difference in survival between the poorest treatment (no protection) and the best (screens) was only 9.6 percent.

Table 1.—*Average survival of sugar maple seedlings 4 years after planting under different protective and weed-control treatments*

Protection treatment	Weed-control treatment			Mean survival
	Sod	Cultivation	Cultivation and plastic mulch	
	Percent	*Percent*	*Percent*	*Percent*
No protection	95.0	86.3	80.0	87.1
Repellent	87.5	92.5	92.5	90.8
Wire screens	98.8	93.8	97.5	96.7
Mean survival	93.8	90.8	90.8	91.5

Growth

Growth differences as a result of weed control and protection, as well as their interaction, were highly significant (0.01 level). Seedlings protected by screens and planted on the plots mulched with black plastic grew best. Their average height after four growing seasons was 44 inches (fig. 2). Screen-protected seedlings planted in sod, and on the cultivated plots, averaged only 25 and 34 inches in height respectively. Little or no differences

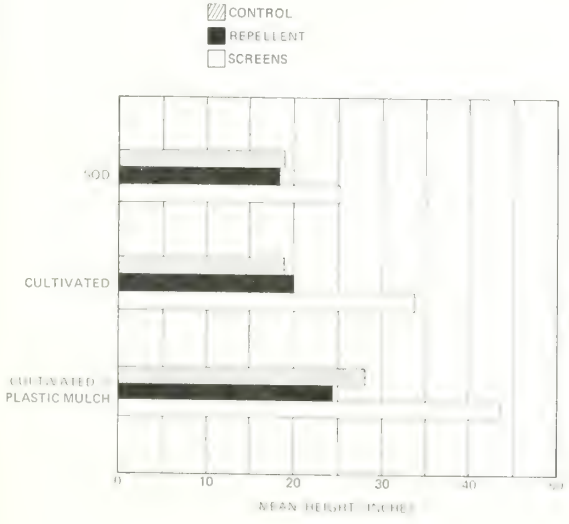

Figure 2.—Mean heights of sugar maple seedlings 4 years after planting under different protective and weed-control treatments.

were found between the unprotected and repellent-treated seedlings. They remained at essentially the same height (about 21 inches) on all plots, similar to when they were planted.

Differences in stem diameter and green stem weight, in general, followed the same pattern as differences in height growth.

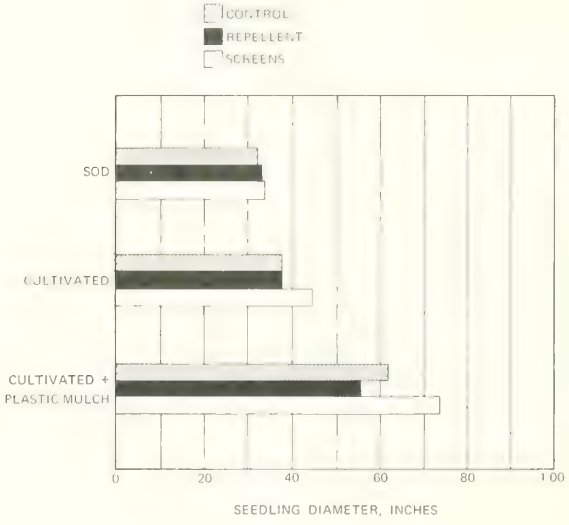

Figure 3.—Mean diameters of sugar maple seedlings 4 years after planting under different protective and weed-control treatments.

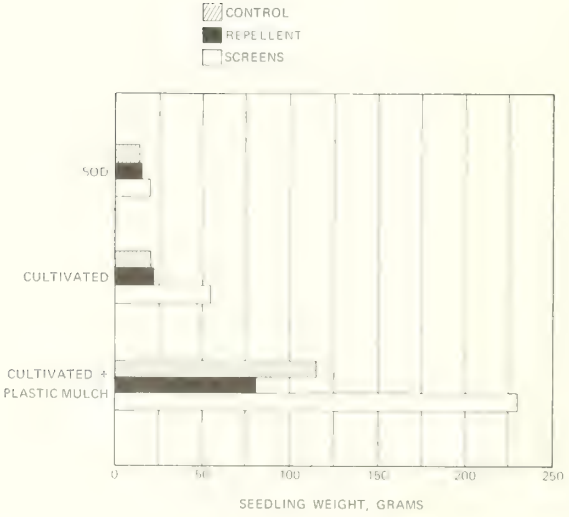

Figure 4. — Fresh stem weights of sugar maple seedlings 4 years after planting under different protective and weed-control treatments.

Stem diameters of the poorest (unprotected on sod plots) and best (screen-protected on mulched plots) treatment combinations averaged 0.32 inch and 0.75 inch respectively (fig. 3).

The greatest growth differences due to treatment, however, were in green stem weight. Average stem weights of the poorest and the best treatments were 14 grams and 206 grams respectively (fig. 4).

DISCUSSION

Survival

The initial high survival rate of 97.5 percent indicates that, if the seedlings are given reasonable care in lifting and handling, sugar maple poses no special planting problems. This study also suggests that fall planting can be done successfully. In many areas fall planting is considered risky because of frost-heaving, but none was observed in this study. Snow, which came shortly after planting and remained throughout the winter, evidently provided good protection against frost-heaving.

Figure 5.—Seedling completely stripped of bark by small field mammals.

Mice and rabbits were thought to be responsible for the initial mortality observed. When we made survival counts in the spring of 1965, we listed as "dead" 18 seedlings that were either missing or were stripped of bark (fig. 5). The "missing" seedlings had had their stems broken off and could not be found in the grass cover. Later, all but one of the "dead" seedlings resprouted; so in later survival counts we listed them as "live". Therefore we attributed the initial seedling losses to animal damage rather than to planting failure.

Over the 4-year study period, mortality increased slightly. The highest mortality was 20.0 percent among the unprotected seedlings planted in the plots that had been cultivated and were covered with black plastic mulch. Mortality was highest on these plots probably because the weed control, afforded by the mulch, made the seedlings more visible for browsing. The mortality for all unprotected seedlings was only 12.9 percent. Such a low

Figure 6.—Weed and grass competition on a sod plot.

Figure 7.—An example of an unprotected seedling repeatedly browsed by deer.

rate is surprising in view of the herbaceous competition on the unmulched plots and the pressure of animal feeding (fig. 6 and fig. 7).

Growth

The results of this study demonstrated the need for eliminating weed and grass competition and animal damage from sugar maple plantings. Sugar maple seedlings are very sensitive to competition from herbaceous vegetation. Growth was shown to improve in relation to the degree of weed control effected by the cultural treatments. Plots covered with black plastic film gave the best weed control, and also the best seedling growth.

Without protection from animals, however, weed control was of little benefit. These seedlings were subjected to repeated deer browsing, and after 4 years they were essentially no higher than when they were planted. The effect of browsing in repressing growth of the exposed seedlings accounts for the significant interaction between the protective and cultural treatments.

Sensitivity of sugar maple seedlings to herbaceous vegetation can be seen by comparing differences in growth between the screen-protected seedlings on both the sod and mulched plots. After four growing seasons, the screened seedlings in sod, which essentially were unbrowsed, had increased their average height by only 4 inches. On the other hand, the screen-protected seedlings mulched with black plastic had more than doubled in height, from 21 to 44 inches. But, because of heavy deer browsing after the seedlings had outgrown the 30-inch high protective screens (fig. 8), the true potential of the mulched plots was masked. Several seedlings that evidently escaped repeated browsing (fig. 9) suggest the kind of growth that may be possible. The tallest of these measured 110 inches in height—representing more than a fivefold increase over the average height at planting.

Diameter growth of the screen-protected seedlings showed similar differences as a result of the sod and mulch treatments:

Figure 8.—Seedlings were heavily deer browsed after they outgrew the 30-inch high screens.

Figure 9.—These seedlings escaped deer browsing. When the study was terminated, the tallest measured 110 inches in height.

seedlings averaged 0.34 and 0.75 inch respectively after 4 years. Treatment differences in stem weight were even more pronounced.

The average fresh weight of the screen-protected seedlings was 20 grams and 206 grams respectively on the sod and mulched plots—a difference in growth of 10 times. If the weight of the 110-inch high tree mentioned before were used to express the treatment potential in the absence of browsing, the growth ratio between the sod and mulched plots would be about 1:40.

Black plastic film effectively controlled herbaceous vegetation. Weeds were completely eliminated the first year except in the small openings around each seedling. Weeds began to appear as the plastic became torn and exposed soil, but even after 4 years it provided considerable weed control. The beneficial aspects of black plastic as a method of controlling weeds has been reported by other investigators *(Walker 1961 and Gabriel 1962)*. However, the growth advantage of the mulched seedlings cannot be attributed to effective weed control alone. Black plastic mulch was found to account for other changes in the soil environment.

Waggoner et al. *(1960)* concluded from their study that, though soil temperatures were only slightly changed, black plastic film did significantly increase available soil moisture by preventing or greatly retarding evaporation.

Eliminating competing vegetation by plowing and disking as a one-time treatment before planting significantly improved growth of the screen-protected seedlings over those planted in sod, but the advantage was short-termed. Re-invasion by weeds occurred rapidly the first year, and weeds fully occupied the plots by the end of the second year.

Except for the screen-protected seedlings planted in sod (because of poor growth they were essentially unbrowsed), all seedlings in all treatments were browsed by deer regardless of the type of protection used. Differences in effectiveness between protective treatments was a matter of timing of seedling exposure to browsing. The repellent was either totally ineffective, or its effectiveness was lost soon after planting.

The 30-inch-high wire screens, which were quite effective during the first year, proved later to be unsatisfactory because the seedlings outgrew them. The answer to deer browsing is to provide more positive protection for a longer period of time. Just how long is suggested by Pearce's *(1937)* observation on the browsing habits of deer in New York State. He concluded that seedlings are subject to deer feeding until they became at least 6 feet tall—the point he found to be beyond reach of browsing deer.

Mice and rabbit damage was found to be relatively light. When the study was terminated, approximately 20 percent of the unprotected and repellent-treated seedlings showed varying signs of basal bark feeding by mice. Only occasional clipping of lateral branches and terminals by rabbits was observed. As expected, the screened seedlings were free of this damage, except in rare instances when the screens were knocked over.

- The results of this study indicated that 2-0 sugar maple seedlings can be planted with reasonable assurance of high initial survival. The study further suggests that fall planting can be successful in Vermont, particularly at the higher elevations. A continuous snow cover throughout the winter, which is typical of such locations, apparently provides good protection from the dangers of frost heaving.
- Sugar maple seedlings appear to be highly sensitive to competing herbaceous vegetation, and elimination of this competition is considered essential during the first few years if rapid early growth is to be achieved. Black plastic film used as mulch was found to be highly effective for this purpose.
- Animal damage was found to be a major problem. Neither the repellent or 30-inch-high wire screens were completely effective. It is apparent that measures are needed that will provide protection until the seedlings have grown beyond the average deer-browsing height of 6 feet.

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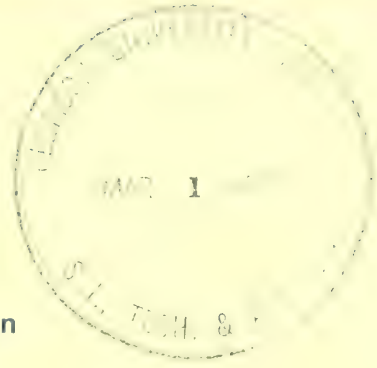
Yields of EASTERN WHITE PINE in New England Related to Age, Site, and Stocking

by William B. Leak
Peter H. Allen
James P. Barrett
Frank K. Beyer
Donald L. Mader
Joseph C. Mawson
Robert K. Wilson



U.S.D.A. FOREST SERVICE RESEARCH PAPER NE-176
1970

NORTHEASTERN FOREST EXPERIMENT STATION, UPPER DARBY, PA
FOREST SERVICE, U.S. DEPARTMENT OF AGRICULTURE
RICHARD D. LANE, DIRECTOR

A Cooperative Study

This paper contains partial results of a cooperative study made jointly by the Universities of Maine, Massachusetts, and New Hampshire, and the Northeastern Forest Experiment Station of the USDA Forest Service. The work was funded by the respective States, the USDA Forest Service, and the Hatch NE-27, Regional Research Project. Computations were run on the IBM 360/40 system at the University of New Hampshire Computation Center.

The primary cooperators in this phase of the study were:
University of Maine: Frank K. Beyer.
University of Massachusetts: Donald L. Mader and Joseph C. Mawson.
University of New Hampshire: James P. Barrett and Peter H. Allen (now with the N. H. Division of Resource Development).
Northeastern Forest Experiment Station: Robert K. Wilson and William B. Leak.

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A STUDY OF THE EFFECTS OF SITE AND STOCKING

EASTERN WHITE PINE (*Pinus strobus* L.) played the leading role in the early lumbering history of New England. This species still is one of the most abundant in the region, accounting for about 20 percent of the board-foot volume in Maine, Massachusetts, and New Hampshire. Although market demands are now moderate, the economic importance of white pine in New England is sure to increase in the future as merchantable timber volumes increase because of better management, including improved insect and disease protection.

Information about growth and yield is basic to the management of any species. Normal yield tables for white pine in New England were developed some time ago *(Frothingham 1914)*, and these tables have proved useful for predicting the yield of unmanaged stands ever since. However, to meet the requirements of more intensive management, we need better methods of predicting growth and yield — methods that reflect site conditions and stocking levels.

To help meet this need, the Universities of Maine, Massachusetts, and New Hampshire, in cooperation with the Northeastern Forest Experiment Station, initiated in 1959-60 a study

of the effects of site and stocking on the growth of eastern white pine. The primary purposes of the study were to develop equations for: (1) predicting the volume increment per acre of pure, even-aged, white pine stands from observable characteristics of the stand, soil, and topography; and (2) predicting the increment of individual white pine trees related to characteristics of the tree, stand, and site.

By 1965, measurements of stand growth and development for a 3-year period were available from nearly all field plots. A preliminary analysis revealed that one or more additional remeasurements should be taken before a final summary of the periodic growth of trees and stands is made. Nevertheless, useful and accurate relationships were developed between stand yield, or volumes per acre, and stand age, site, and stocking; and this information is presented in this paper. Yield tables based on the plot data from New Hampshire, using stand height in place of age and site index, have been published by Barrett and Allen *(1966)*.

FIELD METHODS

Field data were obtained from semipermanent field plots. The plots, located in essentially pure white pine stands that generally had at least 80 percent of the overstory basal area in white pine, were 1/20 to 1/5 acre in size. The condition of both the stand and site within and surrounding each plot was judged to be uniform over an area of about 1/2 acre. Within this 1/2-acre area, the stand was even-aged: the range in age of overstory white pine trees was no more than about 10 years. The stands had not been subjected to major disturbance within the past 15 years or light disturbance within the past 6 years.

A total of 218 plots were available for the yield analysis, excluding any plots that had suffered appreciable damage from cutting during the growth period. The distribution of plots by state, breast-height age class, and initial basal area per acre of overstory pine trees (3.0 inches d.b.h. and over) is shown in table 1. Distribution of plots by 10-foot site-index classes is shown in table 2.

Table 1.—*Distribution of field plots in the white pine yield analysis by state, breast-height age class, and initial basal area per acre of overstory pine trees (3.0 inches d.b.h. and over)*

State	Stand age	Basal area per acre, in square feet		
		51-150	151-250	251 +
	Years	*No.*	*No.*	*No.*
Maine	24 — 50	10	16	3
	51 — 75	10	22	3
	76 +	—	1	—
Mass.	26 — 50	8	45	—
	51 — 75	4	15	4
	76 +	2	3	1
N. H.	26 — 50	8	30	—
	51 — 75	4	20	4
	76 +	—	5	—

Table 2.—*Distribution of field plots in the white pine yield analysis by state and 10-foot site-index classes[1] (b.h. age 50)*

State	Site-index class						All
	40	50	60	70	80	90	
	No.	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*
Maine	—	—	13	41	10	1	65
Mass.	1	3	29	36	11	2	82
N. H.	—	—	16	35	18	2	71
All	1	3	58	112	39	5	218

[1] Height attained by free-growing dominant and codominant white pine trees when 50 years of age at breast height.

Plot measurements used in the yield analysis included:

1. An initial tally of all overstory trees 3.0 inches d.b.h. and larger by species, crown class, and diameter breast high (d.b.h.). Trees in the understory that appeared to represent a younger age class than the main stand were excluded from the yield analysis.

2. Breast-height age, crown class, total height, diameter outside bark (d.o.b.) and diameter inside bark (d.i.b.) of the bole

at 17.3 feet above ground, for as many as 20 sample white pine trees per plot.

3. A stem-analysis of about five dominant or codominant standing pine trees, consisting of paired ring counts and measurements of height-above-ground at a series of points along the bole.

COMPUTATIONS

Equations for individual tree volumes were developed from a series of about 400 white pine stem-analysis diagrams available in the Northeastern Station. Measurements of inside-bark diameter were taken at 4-foot intervals along the bole from these diagrams. Then cubic-foot volume to a 3.0-inch inside-bark top (Smalian's rule) and board-foot volume to a 6.0-inch top (International $\frac{1}{4}$-inch rule) were computed. Regression was used to develop the following equations:

$$\text{Volume in board feet} = -34.57 + 0.0001915\ (\text{D.b.h.})^2\ (\text{HT})\ (\text{GFC})$$

$R = 0.993$

SE (of the mean value) = 1.62 board feet.

$$\text{Volume in cubic feet} = 1.837 + 0.00002636\ (\text{D.b.h.})^2\ (\text{HT})\ (\text{GFC})$$

$R = 0.994$

SE (of the mean value) = 0.206 cubic feet.

Where D.b.h. = diameter in inches at breast height.
HT = total height in feet.
GFC = Girard form class in percent (75%, 80%, etc.).

Plot volumes were computed as follows: A separate linear regression of HT x GFC over d.b.h. was computed for each plot, using data from the sample trees on the plot. Then the volume of each overstory tree was computed by using measured d.b.h. to predict HT x GFC, and inserting measured d.b.h. and predicted HT x GFC into the appropriate volume equation. Cubic-foot volumes were determined for trees 3.0 inches d.b.h. and larger; board-foot volumes were determined for trees 9.0 inches d.b.h. and larger.

Yields, or volumes per acre, were predicted, using three independent variables: mean breast-height stand age, site index, and percent stocking.

Mean breast-height stand age was determined by averaging the ages of the dominant and codominant sample trees on each plot.

Records on the stem-analyzed trees from each state were examined to determine whether available site-index curves could be used. It was found that Frothingham's site-index curves fit the data reasonably well, although some discrepancies were noted at the lower and upper extremes. Thus, the average site index for each plot was estimated from four to five free-growing trees per plot, using Frothingham's site-index curves corrected to breast-height age 50 (fig. 1).

Stocking percent was calculated by dividing basal area per acre in overstory pines (trees 3.0 inches d.b.h. and over) by predicted basal area for a fully stocked stand of the same mean diameter (arithmetic mean). Predicted fully stocked basal area

Figure 1.—Site-index curves for eastern white pine in New England (b.h. age 50) based on Frothingham's site-index curves corrected to a breast height age of 50.

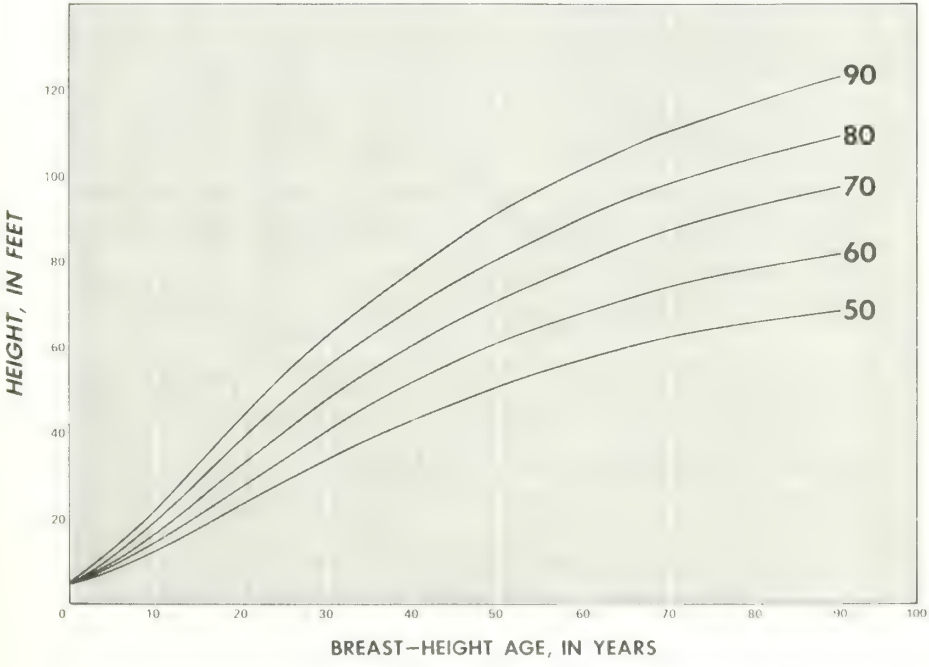
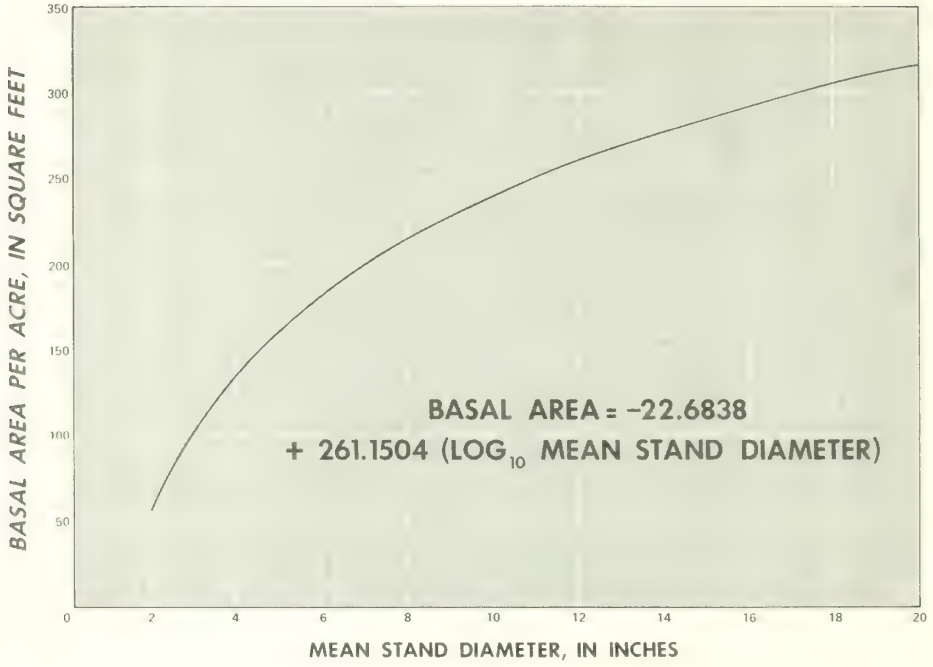


Figure 2.—Fully stocked basal area per acre over mean stand diameter, based on Frothingham's yield data.



was developed from data (all sites combined) presented by Frothingham and expressed as a regression equation (fig. 2):

$$\text{Basal area} = -22.6838 + 261.1504\ (\log_{10} \text{mean stand diameter})$$

Yields were related to age, site, and stocking by regression analysis. We used a slight adaptation of the yield model derived by Clutter *(1963)* for loblolly pine:

$$\text{Log}_{10}\ \text{Yield} = a + b_1(S) + b_2(\log_{10} P) + b_3\ (1/A)$$

Where S = site index.
P = percent stocking.
A = stand age.

In Clutter's model, logarithms were taken to the base e, whereas logarithms in our analysis were taken to the base 10 to facilitate practical use. More important, instead of using basal area in square feet as Clutter did, we used percent stocking, which is

equivalent to relative basal area per acre. This yield model was used to predict both cubic-foot and board-foot yields.

RESULTS

Cubic Feet

The regression equations for cubic-foot volume per acre developed for each state and for all states combined are listed below with corresponding values of R, the multiple correlation coefficient, and SE, the standard error of estimate (the standard deviation of the residuals about the regression surface).[1]

All States: $\text{Log}_{10}\ CV = 1.88039 + 0.00686\ (S) + 0.90268\ (\log_{10}P) - 15.76028\ (1/A)$

Maine: $\text{Log}_{10}\ CV = 1.80868 + 0.00663\ (S) + 0.93192\ (\log_{10}P) - 14.34643\ (1/A)$

Mass.: $\text{Log}_{10}\ CV = 1.92384 + 0.00703\ (S) + 0.88790\ (\log_{10}P) - 16.75412\ (1/A)$

N.H.: $\text{Log}_{10}\ CV = 1.95626 + 0.00677\ (S) + 0.86691\ (\log_{10}P) - 15.88561\ (1/A)$

The correlation is 0.98 and the standard error is 0.8 to 0.9 percent of the mean for each of the four equations.

Examination of the above equations shows that all depict logical relationships; all are highly accurate; and all of them have similar regression coefficients. The pooled variance from the separate equations for each state was less than that for all states combined by an amount that was just significant at the 5-percent level. But practically speaking, the equation for all states combined provides accurate estimates of cubic-foot yield for any state. This combined equation is tabulated in table 3.

Board Feet

The first set of regressions developed for board-foot volumes was based on all 218 plots. However, because of low accuracy and inconsistencies among states, we decided to rerun the re-

[1] Standard errors are expressed as a percentage of the mean, since errors expressed as logarithms or antilogs are not readily interpreted

Table 3.—*Cubic-foot yields per acre to a 3.0-inch i.b. top in Maine, Massachusetts, and New Hampshire, by age, site index (b.h. age 50), and stocking percent*

[Applies to overstory pine trees 3.0 inches d.b.h. and over]

Age (years)	Site Index	Stocking percent									
		40	50	60	70	80	90	100	110	120	130
20	50	761	931	1,098	1,262	1,423	1,583	1,741	1,897	2,052	2,206
	60	892	1,090	1,286	1,477	1,667	1,854	2,039	2,222	2,403	2,583
	70	1,044	1,277	1,506	1,730	1,952	2,171	2,387	2,602	2,814	3,025
	80	1,223	1,496	1,763	2,026	2,286	2,542	2,796	3,047	3,296	3,543
	90	1,432	1,752	2,065	2,373	2,677	2,977	3,274	3,569	3,860	4,149
40	50	1,886	2,307	2,719	3,125	3,526	3,921	4,313	4,700	5,084	5,465
	60	2,209	2,702	3,185	3,660	4,129	4,592	5,051	5,504	5,954	6,400
	70	2,587	3,164	3,730	4,287	4,836	5,378	5,915	6,446	6,973	7,495
	80	3,029	3,075	4,368	5,020	5,663	6,298	6,927	7,549	8,166	8,778
	90	3,548	4,339	5,115	5,879	6,632	7,376	8,112	8,841	9,563	10,280
60	50	2,552	3,121	3,680	4,229	4,771	5,306	5,836	6,360	6,879	7,395
	60	2,989	3,656	4,309	4,953	5,587	6,214	6,834	7,448	8,057	8,660
	70	3,500	4,281	5,047	5,800	6,543	7,277	8,003	8,722	9,435	10,142
	80	4,099	5,014	5,910	6,793	7,663	8,523	9,373	10,215	11,050	11,878
	90	4,800	5,871	6,922	7,955	8,974	9,981	10,977	11,963	12,940	—
80	50	2,968	3,631	4,280	4,919	5,550	6,172	6,788	7,398	8,002	8,602
	60	3,476	4,252	5,013	5,761	6,499	7,228	7,950	8,664	9,372	10,074
	70	4,071	4,980	5,871	6,747	7,611	8,465	9,310	10,146	10,975	11,798
	80	4,768	5,832	6,875	7,902	8,914	9,914	10,903	11,882	12,853	—
	90	5,584	6,830	8,052	9,254	10,439	11,610	12,769	—	—	—
100	50	3,250	3,976	4,687	5,387	6,077	6,758	7,433	8,100	8,762	9,419
	60	3,806	4,656	5,489	6,308	7,116	7,915	8,704	9,486	10,262	11,031
	70	4,458	5,453	6,428	7,388	8,334	9,269	10,194	11,110	12,018	12,918
	80	5,221	6,386	7,528	8,652	9,760	10,855	11,938	—	—	—
	90	6,114	7,478	8,816	10,133	11,431	12,713	—	—	—	—

Table 4.—*Board-foot yields per acre (International ¼-inch rule) to a 6.0-inch i.b. top for eastern white pine in Maine by age, site index (b.h. age 50) and stocking percent.*

[For stands 40 years old or more. Applies to overstory pine trees 9.0 inches d.b.h. and over]

Age (years)	Site index	Stocking percent							
		50	60	70	80	90	100	110	120
40	60	5,742	6,248	6,709	7,136	7,536	7,912	8,269	8,608
	70	8,776	9,548	10,253	10,906	11,517	12,092	12,636	13,155
	80	13,411	14,590	15,669	16,667	17,600	18,478	19,311	20,104
60	60	15,110	16,439	17,654	18,779	19,830	20,820	21,758	22,652
	70	23,091	25,123	26,979	28,697	30,304	31,817	33,251	34,616
	80	35,288	38,392	41,229	43,855	46,310	48,623	50,814	52,900
80	60	24,511	26,667	28,637	30,461	32,167	33,773	35,294	36,744
	70	37,457	40,752	43,763	46,551	49,157	51,612	53,937	56,152
	80	57,242	62,277	66,879	71,139	75,122	78,872	82,426	85,811
100	60	32,765	35,647	38,281	40,720	42,999	45,146	47,180	49,118
	70	50,071	54,476	58,501	62,228	65,711	68,992	72,101	75,061
	80	76,518	83,250	89,401	95,096	100,419	105,434	110,184	114,709

Table 5.—*Board-foot yields per acre (International ¼-inch) to a 6.0-inch i.b. top for eastern white pine in Massachusetts by age, site index (b.h. age 50) and stocking percent*

[For stands 40 years old or more. Applies to overstory pine trees 9.0 inches d.b.h. and over]

Age (years)	Site index	Stocking percent							
		50	60	70	80	90	100	110	120
40	50	5,953	6,587	7,176	7,729	8,251	8,749	9,224	9,681
	60	8,279	9,161	9,980	10,748	11,475	12,167	12,828	13,464
	70	11,513	12,740	13,879	14,948	15,958	16,920	17,840	18,724
	80	16,011	17,718	19,302	20,788	22,193	23,531	24,810	26,039
	90	22,266	24,640	26,842	28,909	30,864	32,724	34,503	36,212
60	50	12,985	14,368	15,653	16,858	17,998	19,083	20,120	21,116
	60	18,058	19,982	21,768	23,444	25,030	26,538	27,981	29,366
	70	25,112	27,789	30,273	32,604	34,808	36,906	38,913	40,840
	80	34,924	38,646	42,100	45,342	48,408	51,325	54,116	56,795
80	50	19,177	21,221	23,118	24,898	26,581	28,183	29,715	31,187
	60	26,669	29,511	32,150	34,625	36,966	39,194	41,325	43,371
	70	37,088	41,041	44,710	48,152	51,408	54,506	57,470	60,316
	80	51,578	57,075	62,178	66,965	71,492	75,802	79,923	83,880
100	50	24,232	26,814	29,211	31,460	33,588	35,612	37,548	39,407
	60	33,699	37,290	40,624	43,752	46,710	49,525	52,218	54,804
	70	46,864	51,859	56,495	60,845	64,959	68,874	72,619	76,215
	80	65,174	72,120	78,567	84,617	90,338	95,782	100,990	105,991

Table 6.—*Board-foot yields per acre (International ¼-inch) to a 6.0-inch i.b. top for eastern white pine in New Hampshire by age, site index (b.h. age 50) and stocking percent*

[For stands 40 years old or more. Applies to overstory pine trees 9.0 inches d.b.h. and over]

Age (years)	Site index	Stocking percent							
		50	60	70	80	90	100	110	120
40	60	7,660	7,876	8,064	8,230	8,379	8,514	8,639	8,755
	70	10,405	10,699	10,953	11,179	11,381	11,566	11,735	11,892
	80	14,134	14,533	14,878	15,184	15,460	15,710	15,940	16,153
60	60	19,864	20,425	20,911	21,341	21,728	22,080	22,403	22,702
	70	26,983	27,744	28,404	28,988	29,514	29,992	30,431	30,838
	80	36,652	37,686	38,582	39,376	40,090	40,739	41,336	41,888
80	60	31,988	32,891	33,673	34,366	34,989	35,556	36,076	36,558
	70	43,451	44,677	45,740	46,681	47,527	48,297	49,004	49,659
100	60	42,574	43,774	44,816	45,738	46,567	47,322	48,014	48,656
	70	57,830	59,461	60,875	62,128	63,254	64,279	65,220	66,092

gressions, excluding all plots in stands less than 40 years old — stands with only a small amount of sawtimber. The resulting regressions were considerably better in both consistency and accuracy. However, because of certain differences among states in predicted values, standard errors, and ranges in the basic data, separate regressions are presented for each state:

Maine: $\text{Log}_{10}\ BV = 3.12884 + 0.01842\ (S) + 0.46245\ (\log_{10}P) - 50.42094\ (1/A)$
$R = 0.79$
$SE = 3.4$ percent of the mean
$N = 48$ plots

Mass.: $\text{Log}_{10}\ BV = 3.13095 + 0.01432\ (S) + 0.55547\ (\log_{10}P) - 40.64337\ (1/A)$
$R = 0.88$
$SE = 2.8$ percent of the mean
$N = 47$ plots

N.H.: $\text{Log}_{10}\ BV = 4.06855 + 0.01330\ (S) + 0.15253\ (\log_{10}P) - 49.65985\ (1/A)$
$R = 0.78$
$SE = 3.9$ percent of the mean
$N = 45$ plots

As might be expected, the equations for board-foot yield were less accurate than those for cubic-foot yield. However, the correlation coefficients and standard errors indicate that this degree of accuracy is useful for practical application.

The three equations are tabulated over the approximate applicable range of data in tables 4, 5, and 6.

APPLICATIONS

The application of yield tables covering a range of stocking percents is complicated by the fact that the stocking percent may change over time.

Where the stocking percent of a stand is near 100 percent — between 90 and 110, for example—changes in stocking percent over time probably can be ignored. For example, beginning with a 40-year-old-stand, on site index 70, and at 100 percent stocking, we would predict 9,310 cubic feet per acre at age 80 (table 3).

Where the initial stocking percent is well above 100 percent, we would assume that the stocking percent would decrease with time. If changes in stocking percent were ignored, estimates of future yield would be overestimated in both cubic feet and board feet. Changes in stocking percent of eastern white pine have not been studied, to our knowledge.[2] However, intensive investigations in western white pine *(Watt 1960)* have shown that changes in stocking percent, or normality percent, are related to initial stocking, age, and composition index:

$$Y = 16.51873 - 0.16165\ X_1 - 0.07555\ X_2 + 0.04267\ X_3$$

Where:

Y = 5-year change in stocking percent.
X_1 = initial stocking percent.
X_2 = stand age in years.
X_3 = composition index (= 100 for a pure pine stand).

Using this equation, we find that percent stocking of a 40-year-old stand, at 120 percent stocking, decreases by not quite 1 percent in 5 years. Thus we might expect such a stand to decrease to about 116 percent stocking by age 60.

Conversely, where initial stocking is below 100 percent, we would expect the stocking percent to increase with time. The main exception would be where hardwoods make up the difference between current pine stocking and full stocking; under such conditions, pine stocking probably would not change greatly with time.

For a 40-year-old stand, the estimated increase in stocking percentage (using Watt's equation) is about 2 percent a year for an initial stocking of 50 percent and about 1 percent a year for an initial stocking of 80 percent. Thus we might expect a 40-year-old stand to increase from 50 percent to 70 percent stocking in roughly 10 years, or from 80 percent to 100 percent in about a 20-year period. We would expect these rates to vary directly with site quality.

[2] Projected hypothetical changes in stocking percent have been applied by Barrett and Allen *(1966)* in their yield analysis of white pine in New Hampshire. However, their correction equation applies to yield tables based on stand height rather than the variables of age and site index used in this paper.

Where the stocking has been reduced by silvicultural treatment, we would expect that stocking percent would increase with time. However, because of improved spacing and vigor as a result of treatment, changes in both stocking percent and volume production would no doubt take place more rapidly than in the unmanaged stands covered by this study.

■

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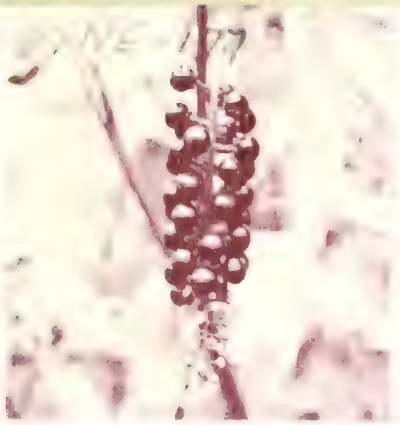

POKEWEED

(Phytolacca americana): Possible Source of a Molluscicide

by Arnold Krochmal
and P. W. LeQuesne

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COVER PHOTO—Birds like the attractive purple fruits of pokeweed, which have been used in Appalachia for a wide variety of home remedies.

MOLLUSCICIDAL PROPERTIES

POKEWEED, A PLANT ABUNDANT in Appalachia, exhibits some chemical similarities to a related species that has shown molluscicidal properties. Because this suggests that pokeweed, *Phytolacca americana* L. (*P. decandra* L.), has potential for controlling fresh-water snails, we have compiled this report of its chemical composition, uses, propagation methods, and other potentially useful species of the genus *Phytolacca.*

The related species, *Phytolacca dodencandra* L'Her, was found to be the source of a molluscicide, which could play an important role in control of bilharziasis, a parasitic disease of humans widespread in Puerto Rico, Africa, and other tropical areas *(22).*

Dead snails and small fish were observed in waterways in areas of Ethiopia where people washed their clothes with this *Phytolacca's* fruit, which is rich in saponins. Some distance downstream and immediately upstream from the washing places, abundant live snails were present, suggesting that the fruit contained a toxin acting as a molluscicide. This was subsequently confirmed by laboratory tests; tap-water extracts of the dried and powdered fruit had an LC_{100} (lethal concentration) of 10 parts per million against snails (*Biomphalaria, Bulinus,* and *Lymnea* spp.) after 24-hour exposure at 23°C. Furthermore, it was shown that molluscicidal potency was not affected by the presence of soil or vegetable matter, an important factor when the molluscicide is used under natural conditions.

BOTANY

The family *Phytolaccaceae* consists of about 17 genera and 125 species of herbs, shrubs, vines, and trees, occurring in the tropics, subtropics, and temperate zones.

Pokeweed is the most widely distributed member of the family native to this country. It is a strong-smelling branching plant that may reach a height of 9 feet, with leaves 4 to 12 inches long. Pokeweed is also known as pokeberry, American nightshade, cancer jalap, cancerroot, chongras, coakum, cocum, cokan, common pokeberry, crowberry, garget, inkberry, jalap, pigeonberry, pocan, pocan bush, poke, pokeroot, red-ink plant, redwood, scoke, skoke, and Virginia poke *(11)*.

The flowers are greenish white to purplish, about 1/4 inch wide, and appear on the vertical stalk in terminal racemes. The dark purplish berries (cover) are attached to the stalk by a short stem. The plant is found in fields, damp woods, roadsides, and strip-mined areas from Maine to Minnesota; south to the Gulf of Mexico and Texas; in Hawaii; and in parts of Europe.

Krochmal *(12)* has demonstrated that pokeweed seed coats are impermeable. Fresh or stored unscarified seeds failed to germinate: scarified seeds, fresh or stored 1 year, germinated.

CHEMISTRY

The roots of pokeweed (fig. 1) were mentioned in early American medicine as the source of a powerful drug, which in small doses was thought useful for the treatment of ulcers and skin disorders *(5)*. Toxic effects were noted with large doses. Much of the early literature has been summarized by Jenkins *(9)*, who also performed the first systematic chemical study of the plant. A pungent-smelling essential oil and an uncharacterized fraction giving positive alkaloid tests were the main organic extractives of interest.

In 1936, Goldstein and Jenkins *(6)* isolated and identified an unsaturated sterol, $C_{23}H_{40}O$, and a triterpenol, $C_{30}H_{50}O$, from the chloroform-extracted non-volatile oil of the roots. Several fatty acids were present as esters.

Figure 1.—Roots of Pokeweed.

In 1949, Jenkins and his co-workers *(1)* reported a more thorough search for alkaloid constituents, with only negative results; but the presence of starch, gum, oxalates, potassium nitrate in considerable quantities, hemicelluloses, and the toxic saponin was established. The physiological properties of this compound, which is characterized by melting point (m.p.) 212°F. (decomposition) and empirical formula $C_{51}H_{90}O_{22} \cdot 2H_2O$ $[\alpha]_D^{25}$ + 46°F. ethyl alcohol, showed that it is responsible for the medicinal properties of the roots. It has a strong hemolytic action, is toxic to protozoa and fish, is strongly irritant to the gastro-intestinal and respiratory tracts, and depresses circulation and respiration in rabbits. A second compound, melting point 159-162°F., $C_9H_{17}O_4$, was also obtained. It was physiologically inactive.

In 1964, Stout, Malofsky, and Stout *(19)* described a further extraction of the toxic compound from pokeweed roots, and named it phytolaccatoxin. Acid hydrolysis of this compound gave glucose and xylose. A sapogenin named phytolaccagenin, melting point 317-318°F. (decomposition), $C_{31}H_{48}O_7$, was identified by paper chromatography. This compound was investigated by X-ray chrystallography, which showed the structure to be that shown in fig. 2 (I). This highly oxygenated structure is characteristic of several physiologically active triterpenoids discovered in recent years. Also, it is closely related to the well known oleanic acid shown in fig. 2 (II). This compound has

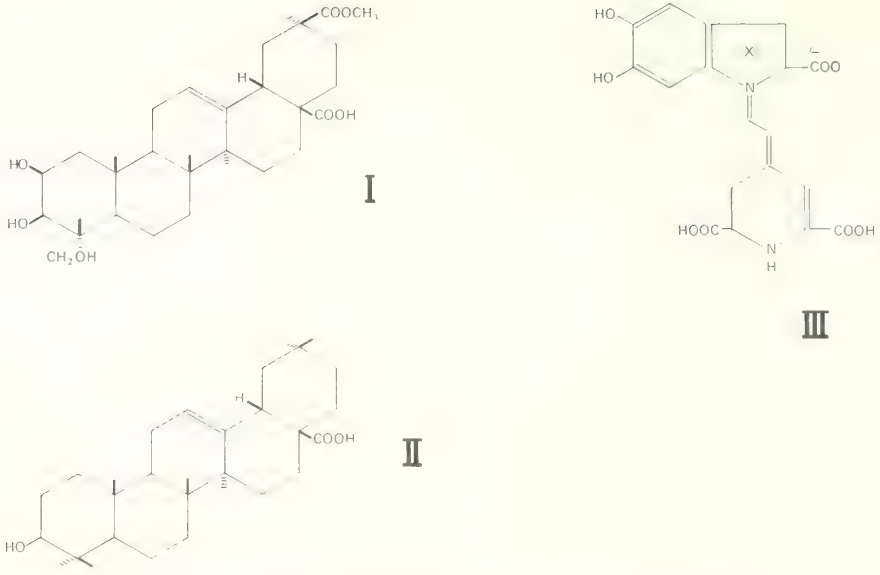


Figure 2.—Structures of (I) phytolaccagenin, (II) oleanic acid, and (III) betanin.

been identified as the aglycone of a powerful molluscicidal saponin isolated from *Phytolacca dodecandra.*

The purple color of the berries of pokeweed is due to the pigment betanin (fig. 2 (III)), which is commonly found in many plants of the family Centrospermae *(17).*

A mitogenic substance has been reported in pokeweed *(3,4)* and is being investigated at the National Institute of Health.

TOXIC PROPERTIES

The root is the most poisonous part of the plant, and most serious illnesses attributed to pokeweed result from the mistaking of roots for parsnips or horseradish *(13).*

An alcohol extract of the root yielded a resin-like material, which acted as a powerful depressant to the central nervous system and was fatal to cats in doses of 50 mg. per kilo body weight *(7).*

An aqueous extract containing a saponin was a topical irritant and emetic *(7).*

Cats vomited violently when 5 to 10 ml. of fluid-extract was administered; 4 ml. of fluid-extract, alcohol-free, stopped heart beat and respiration *(14)*.

Poisoning symptoms include vomiting 1 to 2 hours after ingestion, often without pain or spasm; drowsiness; dizziness; and poor vision *(13)*. In extreme cases, the toxin can cause convulsions and death due to paralysis of the respiratory organs *(15)*.

The berries are relatively nontoxic and have been used in pies without adverse reactions. Nevertheless, uncooked berries may possess sufficient toxin to affect children.

USES

In the 24th edition of the DISPENSATORY OF THE UNITED STATES OF AMERICA *(16)*, the definition of *Phytolacca* is the "dried root of *P. americana*", and for medicinal purposes that is the most commonly used part. It has been used in the treatment of parasitic skin diseases and chronic rheumatism. The fruit juice reportedly has been used to treat tremors, cancer, and hemorrhoids; and as a diuretic *(10)* alternative, emetic, and purgative *(20)*.

In certain sections of the southeastern United States, the sprouts and stems are boiled and eaten after discarding the water. These cooked greens are known colloquially as sallets (salads). Newcomers to Appalachia have sometimes prepared salads from overly mature pokeweed, precipitating cases of moderate to severe poisoning.

In Appalachia, a wine made of ripe fresh pokeweed berries has been used for the treatment of rheumatism.

In the Pennsylvania Dutch regions, the berries were used to make ink and to color wines *(23)*. The plant is believed to have mild laxative qualities.

Although rarely prescribed in the United Kingdom, it is considered to be mildly narcotic, emetic, and purgative and has been prescribed to treat rheumatism *(21)*.

In Spain, a pomade made of the roots is used to treat skin eruptions, skin rash, and ringworm *(18)*. The fruit is used as a purgative and emetic.

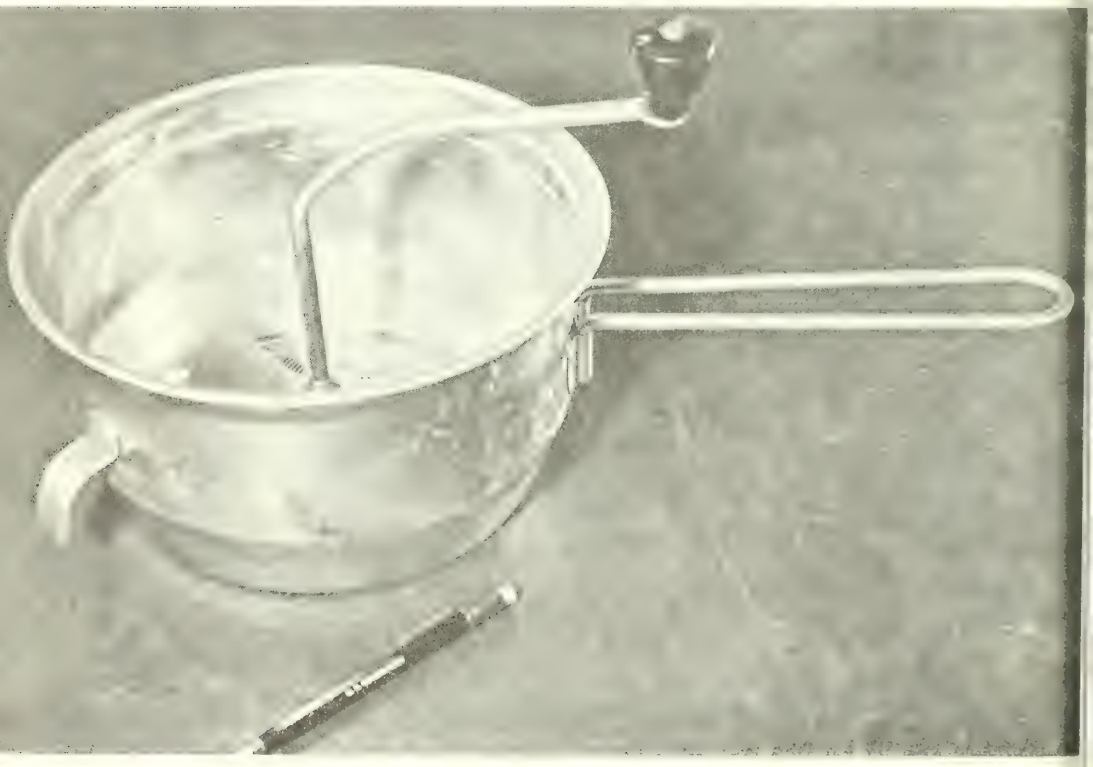
EXTRACTING JUICE FROM BERRIES

Saponin-containing plants and plant parts are not easy to work with, because separation methods are tedious and cumbersome because of the viscous nature of the saponins.

To obtain juice for analyses, we used a hand-operated mechanical colander (fig. 3). In the first pressings, the juice flowed freely; but towards the end, we found increasing quantities of saponins adhering to the seeds.

As this sticky material was pressed from the seeds, we removed it from the underside of the screen with a rubber spatula. The liquid was then put into triple plastic refrigerator bags and was frozen for subsequent analyses.

Figure 3.—Colander used in extracting juice from pokeweed berries.



OTHER POTENTIALLY USEFUL SPECIES

P. acinosa **Roxb.**—Tropical Asia, China, Japan, and Himalayas. Cultivated in some parts of India. The berries are used in Chinese medical practice, and the boiled leaves are eaten as a vegetable. During the middle 1800's, it was grown in Germany, and eaten as a vegetable *(8)*.

P. chilensis **Miers. Carmin.**—Chile. The berries are used as a dye *(22)*.

P. dodecandra **L. (*P. abyssinica* Hoffm.)**—Ethiopia, Guinea, and other areas of Africa. Believed to exhibit molluscicidal properties in Ethiopia. Young leaves are eaten *(2)*.

P. octandra **L.**—Mexico, Guinea, and Jamaica. Green fruits are used to make suds for washing clothes. Parts of the plant are used in Sonora and Baja California, Mexico, to treat rabies. It has been cultivated in home gardens in Jamaica. It is eaten in China *(8,15)*.

P. rivinoides **L. Kunt, and Bouche.**—South and Central America. Roots used as a soap substitute. The cooked leaves and shoots are eaten as a vegetable in some areas *(22)*.

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by Arnold Krochmal
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Lobeline Content of **LOBELIA INFLATA** : Structural, Environmental and Developmental Effects

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LOBELIA INFLATA L.

(Campanulaceae)

COMMON NAMES: Indian tobacco, asthma weed, bladder pod, bladder-podded lobelia, emetic herb, emetic weed, eyebright, field lobelia, gagroot, Indian tobacco lobelia, lobelia, obelia, pukeweed, tobacca lobelia, vomitwort, wild tobacco.

DESCRIPTION: A branching annual that grows to 3 feet in height. Leaves are 1 to 3 inches long. Produces small, violet-pinkish-white flowers situated in axils of alternate leaves, the bottom of which greatly inflate in fruiting stage.

FLOWERING PERIOD: July to September.

HABITAT: Weedy fields, roadsides, woods, and in partial shade.

HARVEST: Herb when in flower and forming seeds.

USES: The herb yields the alkaloid lobeline, which is used in anti-tobacco therapy. It is also used as a stimulant, antiasthmatic, and expectorant in cases of bronchitis. It is also used to measure circulation time (7).

From A Guide to Medicinal Plants of Appalachia (4)

A RESEARCH PROGRAM is being carried on to develop methods for germinating and cultivating *Lobelia inflata* L., a native forest plant that is the principal source of the alkaloid lobeline, which is used in an increasing number of anti-smoking preparations. The goal is to produce maximum lobeline yields.

To aid in estimating the quantities of plants required to meet the demand for lobeline, we have studied lobeline content as influenced by the age of the plant; the distribution of lobeline within different parts of the plant; lobeline content in relation to soil pH, phosphorous, potassium, and organic matter; and lobeline content as indicated by plant levels of nitrogen, phosphorus, and potassium.

BACKGROUND

The principal supply of lobeline comes from wild plants collected in the Appalachian Region of the eastern United States (*4*). But as social changes occur in Appalachia, a dwindling number of people are willing or able to collect plants in the forests. So the possibility of growing *L. inflata* as a cultivated plant in the forests merits careful study. The goal is maximum production of lobeline per acre rather than plants per acre.

A survey of anti-smoking preparations in tablet and pastille forms shows a range of content from 0.5 mg. to 2.0 mg. lobeline per tablet or pastille. The total quantity of lobeline used in the United States is not known. One company estimates that it purchases 50,000 to 75,000 pounds of *L. inflata* plant material

annually.[1] Another company estimates its purchases at to be about 30,000 pounds per year.[2] The authors estimate that about 300 to 400 pounds of lobeline is used per year for anti-smoking preparations.

Field Study

Field studies were begun in the summer of 1967 to investigate the influence of soil pH, organic matter, potassium, and phosphorous on lobeline synthesis; to determine if plant analyses of nitrogen, phosporous, and potassium were suitable indicators of lobeline content; to study the distribution of lobeline within the plant; and to study lobeline content as related to stage of plant growth.

A very uniform, level, fallow cornfield with a high population of *L. inflata,* located in Madison County, Kentucky, was selected for a study site to minimize differences of drainage, slope, exposure, and other ecological factors. Some of the differences we were interested in related to soil fertility and we believed that soil variability would be enough within this limited area to show in soil analyses.

Fifty samples of above-ground portions of *L. inflata* were harvested from 0.8-meter square plots. A measuring circle was tossed at random and all *L. inflata* plants in the circle were harvested. If no plants were included, the device was thrown again. After drying in a forced hot-air drying box, the plant material was passed through the 40-mesh screen of a Wiley mill. The ground material was divided into two parts, one for lobeline analyses and the other for plant-nutrient analyses. Three soil samples, to a depth of 12 inches, were taken from each plot, composited, and dried in a laboratory oven.

[1] Wilcox Drug Company, Boone, North Carolina; personal communication, 1970.
[2] Coeburn Produce Company, Coeburn, Viriginia; personal communication, 1970.

For the studies of lobeline content in relation to plant age and plant organs, plants at the desired stage of maturity were harvested from the entire field and then were divided into 6 groups of 10 plants each. Studies of organs were based on 60 mature plants, divided into 6 groups of 10 plants each. Above-ground plant parts were used for both these studies.

Minerals and pH

Soil and plant mineral analyses were performed with standard methods. Total nitrogen was determined with regular Kjeldahl procedure and phosphorus and potassium with a Technicon Auto Analyzer.

Soil pH was determined at a 1:1 soil:water ratio. Organic matter was determined with a Walkley-Black heat-of-dilution method; phosphorus with the Bray No. 1 soil test, 1:10 ratio; and potassium with 0.15*N* H_2SO_4 extraction for 2 minutes and flame photometer.

Lobeline

Five-g. portions of coarsely powdered dried plant material were extracted continuously for 16 hours in a Soxhlet extractor, using 120 ml. of chloroform. When larger samples were available, 10-g. portions were extracted in a similar manner except that two consecutive extractions of 10 hours each were made, using 120 ml. of fresh chloroform for the second extraction.

The total chloroform extract from each sample was concentrated in a flash evaporator at a temperature below 20°C.; and the resulting residue was weighed, then redissolved in chloroform to exactly 10 ml. in a volumetric flask. Very small samples were diluted to 5 ml. with chloroform.

Of each of the resulting solutions, 0.2 ml. was steamed on a Silicagel-G preparative plate 0.5 mm. thick. These plates were developed with a cyclohexane : chloroform : diethylamine (50 : 40 : 10) solvent system (*13*).

The developed plates were dried, then were examined under long- and short-wave ultraviolet light and exposed to various alkaloid reagent sprays such as Dragendorff's reagent and iodine

vapors. Lobeline was identified by chromatography by comparing it with an authenic sample. By comparison of spotting on a plate, resulting from a known lobeline sample, and by comparison of R_f values, the band corresponding to lobeline was identified.

This material was removed from the plate and eluted with chloroform. The infrared and ultraviolet spectra of the dried eluted material compared favorably with the spectra of known lobeline and were different from the spectra of lobelanine and lobelanidine. The band identified as lobeline with an R_f value of 0.63 was removed from the plate of each sample, eluted with chloroform in a microcolumn, and diluted to known volume; and the concentration of the resulting solution was determined with a Beckman DB-G spectrophotometer at a wave length of 250 mu. (*10*). The lobeline content of the dried plant was then calculated.

Spots indicating the possible presence of as many as five alkaloids (*11*) were obtained from some of the samples.

Development and Lobeline Content

Collectors of *L. inflata* harvest the above-ground parts of mature plants along with flowers and seeds, although pharmacopoeias (*8, 13*) refer to *lobelia* as the dried aerial parts or tops, omitting reference to flowers. In Great Britain (*12*) a minimum alkaloid quantity, calculated as lobeline, is specified at 0.3 percent.

Juvenile, adolescent, and mature plants (table 1 and figs. 1, 2, 3) were analyzed for lobeline. Lobeline concentration decreased with maturity, but total plant lobeline content actually increased with maturity (table 1).

Mature flowering plants were found to average 0.76 percent lobeline; adolescent plants 1.46 percent, and juvenile plants in the rosette stage 1.95 percent (table 1).

Tests of difference were based on Tukey's method (9) applied to log-transformed data:

	Mean % lobeline
Juvenile	1.95
Adolescent	1.46
Mature	0.76

The only means that were not significantly different between maturity classes at the 5-percent level of significance were the means for percent lobeline for the juvenile and adolescent groups. This is indicated by the brace in the above tabulation.

Table 1.—Percentage of lobeline occurring in *Lobelia inflata* at three stages of growth

[Dry-weight basis]

Growth stage	Lot	Lobeline
	No.	*Percent*
Juvenile [1]	100	1.41
	101	1.81
	102	.89
	103	4.28
	104	2.02
	105	1.27
Mean	—	1.95
Adolescent [2]	200	1.81
	201	1.47
	202	2.82
	203	.46
	204	.87
	205	1.33
Mean	—	1.46
Mature [3]	400	0.98
	401	.67
	402	.72
	403	.80
	404	.69
	405	.69
Mean	—	0.76

[1] Juvenile—basal rosettes not yet elongated into a stem.

[2] Adolescent—plants with elongated stems but without flowers or seed capsules.

[3] Mature—branched, with inflated capsules and flowers.

Figure 1.—Laboratory-grown Lobelia inflata plants.

Figure 2.—A young rosette of Lobelia inflata, compared in size with a half dollar (white disk).

Figure 3.—A mature plant of Lobelia inflata, showing seed capsules and some flowers.

Structure and Lobeline Content

Leaves, stems, and flowers from mature plants were analyzed separately to determine levels of lobeline occurring in the different above-ground parts of the plant.

Structural differences in lobeline concentration were noted. Leaves analyzed 0.38 percent and stems 0.58 percent (table 2). The greatest concentration of the alkaloid was found in the flowers, which yielded 3.03 percent, eight times more lobeline than the leaves and over five times more than the stems.

Table 2.—Lobeline content of different plant parts

[Dry-weight basis]

Part	Lot	Lobeline content
	No.	
Leaves	300	0.35
	301	.36
	302	.33
	303	.69
	304	.33
	305	.20
Mean	—	0.38
Stems	300	0.41
	301	.38
	302	.57
	303	.80
	304	.40
	305	.90
Mean	—	0.58
Flowers	300	3.22
	301	2.34
	302	2.04
	303	5.95
	304	3.31
	305	1.34
Mean	—	3.03

An analysis of variance on the log-transformed data showed no effect due to lot, and showed that the lobeline concentration in leaves and stems is not significantly different at the 5-percent level of significance.

In Italy (*8*) lower lobeline yields were reported, flowers containing an average of 1.0 percent, leaves 0.4 percent, and entire plants 0.55 percent. These differences may reflect different analytical methods, different ecological conditions, experimental variability, or a combination of these factors.

Environment and Lobeline Synthesis

Differences in alkaloid content of *L. inflata* from different soils have been reported (*2*), suggesting that differences may be attributed to the state of plant nutrition, analytical techniques, and soil variation.

Hoffman (*3*) reported high levels of soil nitrogen and P_2O_5 to be associated with high alkaloid content. An increase in alkaloid content with increase in soil K_2O has also been reported (*1*).

On the other hand, studies of the effects of different forms of nitrogen, phosphorus, and potassium on lobeline formation have led to the conclusion that fresh weight can be increased by the use of fertilizers, but that alkaloid content (or percent concentration) decreased under such trials by as much as 2.5 times (*6*).

A response surface was used up to second-order values of soil pH in fitting the 50 data points. Optimal conditions for lobeline production could not be determined. In fact, the observed pH, organic matter, and phosphorus and potassium levels of the soil as related to lobeline content could be attributed to the random fluctuations observed in this experiment ($F_{11,19} = .794$); that is, statistical analysis of the data in table 3 revealed no relation between the measurements of these soil properties and lobeline content.

In a detailed study of the relation between plant growth and lobeline production, it was noted that growth responses to the addition of fertiliizers were not tied to a proportionate increase in lobeline production (*5*). The greatest increase in vegetative material came from the use of phosphorus in combination with nitrogen from sulfate of ammonia.

Plant Nutrient Levels

Since analyses for nitrogen, phosphorus, and potassium are easier and less expensive than those for lobeline, it was interesting to determine whether levels of nitrogen, phosphorus, and potassium in plant tissue could be related to those of lobeline. Our statistical analysis did not establish any such relationship. The effects of N, K, and P could not be distinguished from the

Table 3.—Mineral analyses of plants and soil from fallow corn-field in Madison County, Berea, Kentucky

Sample No.	Plant			Soil				Lobeline, percent of dry weight
	N	P	K	pH	Organic matter	K	P	
	Pct.	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Lbs./acre*	*Lbs./acre*	*Pct.*
1	1.92	0.26	1.53	4.5	—	57	22	0.67
2	1.35	.17	1.56	4.5	—	92	23	1.34
3	1.32	.16	1.43	4.7	—	53	13	.60
4	1.28	.14	1.22	4.6	—	62	11	2.38
5	1.21	.15	1.18	5.3	—	62	11	.62
6	1.40	.15	.85	4.5	—	53	20	1.23
7	1.34	.17	1.45	4.6	—	48	10	.44
8	1.33	.15	.76	4.6	—	47	13	.46
9	1.13	.15	.15	4.8	—	54	12	.65
10	1.33	.14	.89	4.8	—	50	11	.23
11	1.28	.17	1.40	4.3	—	55	9	.78
12	1.01	.16	1.62	4.4	—	58	19	.87
13	1.41	.15	1.07	4.7	—	57	10	.93
14	1.27	.13	1.15	5.8	—	71	12	.96
15	1.45	.17	1.69	5.2	—	72	9	1.04
16	1.31	.16	1.54	4.6	—	68	13	.46
17	1.43	.13	1.29	5.0	—	70	12	.35
18	1.22	.13	1.02	4.7	—	64	18	.41
19	1.06	.14	1.44	4.6	—	62	11	.54
20	1.10	.12	1.50	4.2	2.54	90	9	.70
21	1.72	.13	1.35	4.5	3.96	71	16	.63
22	1.13	.15	1.19	4.5	3.57	67	16	.53

23	1.13	.14	1.32	4.5	2.83	70	21	.52
24	1.41	.14	1.08	5.0	3.39	81	14	.61
25	1.57	.15	1.44	4.9	3.14	72	10	.65
26	1.41	.14	1.36	4.6	2.09	69	17	.60
27	1.22	.14	1.58	4.6	1.82	70	20	1.31
28	1.38	.12	1.17	4.3	3.27	72	25	1.22
29	1.34	.15	1.45	4.6	3.63	70	32	.52
30	1.39	.16	1.40	4.4	3.13	69	24	.56
31	.99	.19	1.83	4.3	3.07	90	36	.28
32	1.66	.13	1.09	4.6	4.02	74	32	.34
33	1.49	.15	1.32	4.5	3.33	75	36	.67
34	1.08	.15	1.42	4.3	2.70	95	40	.36
35	1.31	.12	1.12	4.2	2.35	83	35	.19
36	1.32	.14	1.04	4.3	3.73	63	42	.53
37	1.04	.09	.96	4.3	2.35	65	26	.19
38	1.13	.15	1.37	4.1	2.70	70	39	.50
39	.83	.14	1.14	4.1	4.03	68	44	.40
40	.81	.14	1.47	4.1	3.67	70	38	.25
41	.96	.12	1.22	4.2	3.48	72	42	.53
42	1.00	.14	1.11	4.4	3.24	70	37	.41
43	1.40	.20	1.88	4.5	3.12	73	48	.51
44	1.25	.17	1.48	4.4	3.19	63	41	.85
45	1.21	.15	1.53	4.5	3.31	71	23	.60
46	1.16	.14	1.62	4.5	4.30	80	36	.60
47	1.54	.15	1.57	4.4	4.10	83	29	.45
48	.93	.14	1.69	4.4	4.15	79	30	.20
49	1.25	.15	1.75	4.4	3.96	66	26	.50
50	1.21	.18	1.60	4.2	4.41	60	43	.55
Range	0.81+	0.09+	0.76+	4.1+	1.82+	47+	9+	0.19+
	—1.92	—0.26	—1.88	—5.8	—4.41	—75	—48	—2.38

random fluctuations in the measured levels of lobeline ($F_{9,40} = .798$).

SUMMARY

We found that lobeline concentrations decrease from juvenile to mature plants, but that total amounts of lobeline per plant increase from juvenile to mature plants.

A comparison of lobeline concentrations in plant parts showed a small difference between leaves and stems, but a markedly higher concentration in flowers.

Within the range of conditions encountered in this study, we found no relationship between lobeline content and plant levels of nitrogen, phosphorus, and potassium, and no relationship between lobeline content and soil pH, organic matter, phosphorus, or potassium.

Conclusion

Because no relationship could be found between soil organic matter, phosphorus, potassium, pH, and lobeline content in the plants we analyzed, we conclude that: (1) these factors were at a suitable level for lobeline synthesis; (2) the plants' ability to synthesize lobeline was not sensitive to the differences in the levels of these minerals encountered in this experiment; (3) the minerals studied, phosphorus and potassium, soil organic matter, and pH were too uniform to be reflected in any differences in lobeline synthesis in *L. inflata*.

Mature flowering plants provide a maximum yield of lobeline because of the high lobeline content of the flowers and the weight of the mature plants.

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THE FOREST SERVICE of the U. S. Department of Agriculture is dedicated to the principle of multiple use management of the Nation's forest resources for sustained yields of wood, water, forage, wildlife, and recreation. Through forestry research, cooperation with the States and private forest owners, and management of the National Forests and National Grasslands, it strives — as directed by Congress — to provide increasingly greater service to a growing Nation.

SPROUTING of DORMANT BUDS on border trees

by G. R. Trimble, Jr.
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NORTHEASTERN FOREST EXPERIMENT STATION, UPPER DARBY, PA.
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AS PART OF an evaluation of silvicultural systems used in managing Appalachian hardwoods, we are studying degrade of border trees surrounding harvest-cut openings made in the patch cutting and group selection systems. One facet of this research dealt with determining what portion of visually evident dormant buds on border tree boles sprouted when the openings were cut. Increased knowledge in this area, along with more information about other aspects of bole sprouting, should lead to forest practices better designed to protect log quality.

As a result of this research on dormant buds, we learned that a higher proportion of buds sprouted on red oak than on yellow-poplar, that a higher proportion sprouted on exposed than on unexposed bole faces, that bud sprouting increased with height on the bole, and that most bud sprouting occurred in the growing season after release.

Study Procedure

The study was made on border trees surrounding 12 clearcut openings 200 to 250 feet in diameter (fig. 1). The openings were made in early summer, 1965, in a 50-acre stand of even-age mixed hardwoods near Parsons, West Virginia. The undisturbed and well-stocked stand was about 60 years old and had a site index of between 70 and 80 feet for oak (*Schnur 1937*).

For study trees, we designated at random 29 northern red oaks (*Quercus rubra* L.) and 21 yellow-poplars (*Liriodendron tulipifera* L.) that were between 10 and 22 inches d.b.h. Because crown dominance has been shown to affect the extent of epicormic branching that occurs when tree boles are suddenly exposed, we limited our selection of study trees to the codominant class and thus eliminated crown class as a study variable.

Figure 1.—Patch cutting opening.

Figure 2. — Epicormic branches on exposed half of a codominant red oak, 2 years after patch cutting. Buds and branches were marked with paint as they were tallied.

Initially, for each study tree, we recorded species and d.b.h. Also, we tallied all the dormant buds that were visible on the bole surface and circled them with paint. We did this to a height of two (16-foot) logs, separately for the half-bole circumference facing into the opening and for the half facing into the stand; these were designated the "exposed half" and the "unexposed half".

We considered dormant buds as any visually identifiable live buds, or bud clusters (buds in a cluster were counted as one bud) on the surface of the bark or embedded in it. For a more detailed explanation of the different types of buds, their origin, and their sprouting characteristics, readers should refer to a recent paper by Kormanik and Brown (*1969*).

After 1½ growing seasons (in the fall of 1966) and again after 3 more growing seasons (in October 1969), we repeated the d.b.h. measurement, counted new dormant buds that had appeared in the interim, and tallied the dormant buds that had sprouted since the previous measurement (fig. 2).

PERCENT OF VISUALLY EVIDENT DORMANT BUDS THAT SPROUT

We tested the effect of several variables on bud sprouting: (1) species; (2) position on bole in relation to release, i.e. exposed versus unexposed half; (3) height on bole; and (4) elapsed time from release.

In considering the results of this study, readers should keep in mind that this study was limited to two species and to middle-aged trees of codominant crown class. Other species, younger trees, and stems of more subdominant crown classes would undoubtedly react differently under the same conditions.

Species

Over the 4½-year study period, a higher percentage of originally tallied buds sprouted on red oaks than on yellow-poplars. For the exposed halves of the first two logs, the figures were 18 and 7 percent (table 1). The difference was significant at the 1-

Table 1.—*Average number of initial dormant buds and percent of buds that sprouted per 16-foot log section*

Species	First log		Second log		First and second logs	
	Dormant buds	Sprouted	Dormant buds	Sprouted	Dormant buds	Sprouted
	No.	*Pct.*	*No.*	*Pct.*	*No.*	*Pct.*
			EXPOSED HALF			
Red oak (29 trees)	37	15	37	20	74	18
Yellow-poplar (21 trees)	4	4	10	11	14	7
			UNEXPOSED HALF			
Red oak (29 trees)	37	6	32	9	69	8
Yellow-poplar (21 trees)	4	5	10	6	14	6

percent level. For the unexposed halves, the percentages were 8 and 6, a difference of only 2 percent (and not significant at the 5-percent level).

In addition to indicating that release triggered a higher percentage of red oak (than yellow-poplar) domant buds to sprout, the study showed that at the time of release red oaks had a greater number of buds (table 1). The results of this phase of the study were summarized and published by Smith (*1967*).

Exposed Half vs. Unexposed Half

For red oak, based on the first two logs, the exposed half had an average sprouting rate of 18 percent compared to 8 percent for the unexposed half. The difference was statistically significant at the 1-percent level. For yellow-poplar, the sprouting percentages were 7 for the exposed and 6 for the unexposed halves, and the difference was not significant at the 5-percent level.

Not only did the exposed sides of the boles sprout more profusely on the average, but sprouting on the unexposed half was concentrated near the borders of the exposed half. Moreover, where sprouting was heavier on the side of the bole facing into the stand (normally the unexposed face), this face had usually been unavoidably exposed when the openings were cut.

Height on Bole

The study showed that on the exposed boles of both species, the percent of originally tallied buds that sprouted increased with height on the bole.

For red oak, 15 percent of the buds on the first log sprouted, compared to 20 percent that sprouted on the second log; this difference between logs was significant at the 1-percent level. For yellow-poplar, 4 percent of the buds sprouted on the first log, and 11 percent sprouted on the second; the difference was not significant at the 5-percent level (possibly because so few trees had buds that sprouted).

The trend toward more bud sprouting with increased height on the tree bole conforms to previous work showing that released trees increase in epicormic branching with height above ground

(*Jemison and Schumacher 1948; Wahlenberg 1950; Smith 1965 and 1966*).

Elapsed Time after Release

About 1½ growing seasons passed between the initial count of dormant buds (taken shortly after release) and the first tally of buds that had sprouted in the interim; 3 more growing seasons passed before the next tally. For the exposed halves, we found these relationships between time since release and occurrence of sprouting:

Red oak.—On the first log, an average of six initially tallied buds sprouted. Of these, 77 percent sprouted in the first 1½ growing seasons. The second log had an average of 8 buds sprouting; 78 percent of them sprouted in the first 1½ growing seasons.

Yellow-poplar.—This species had little sprouting. In fact, the first log had practically no new sprouts. On the second log an average of one bud sprouted per tree. Nearly all sprouting (88 percent) on both logs occurred during the first measurement period (1½ years after exposure).

These data show that most post-release sprouting took place shortly after the trees were released. Had the study been continued, it is likely that very few additional buds would have been found to sprout. Moreover, our observations indicated that, after the first 2 years, mortality among sprouts probably exceeded in number the additional buds sprouting; although we did not count them at the last measurement, we noticed a great many dead epicormic branches.

DORMANT BUDS vs. BUDS SPROUTING

We calculated the correlation coefficients between the number of original buds and the percent of buds that sprouted in an attempt to discover if factors producing greater numbers of buds also operated to produce a higher sprouting rate. We made this test for the exposed halves of the first and second logs of red oaks. (Oaks had enough buds for tests of this nature to be meaningful; yellow-poplars did not). In both cases, the coefficients were small and not statistically significant, indicating that little, if any, relationship existed.

Summary

From a study of dormant bud sprouting made after release on 29 red oak and 21 yellow-poplar codominant border trees, we determined that:

- A higher percentage of dormant buds sprouted on red oaks than on yellow-poplars.
- A higher percentage of buds sprouted on the exposed than on the unexposed half of the tree bole.
- A higher percentage of buds sprouted on the second log than on the first log.
- Of the buds that sprouted in 4½ years after release, most sprouted during the first 1½ years.
- On the exposed half of the first and second logs of red oaks, no significant correlations existed between number of dormant buds and percentage of buds sprouting.
- The sprouting percentage of the few new buds that appeared during the study was higher than the sprouting percentage of the original buds.

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THE SHOLO MILL:

Make Pallet Parts and Pulp Chips from Low-Grade Hardwoods

CLEMSON UNIVERSITY
JUN 28 1971
TECH. & AGR.

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THE SHORT LOG PROCESS

SHOLO (from SHOrt LOg) is a new solution to the old problem of profitably converting low-grade hardwood logs into products or product parts. It does away with the traditional and often uneconomical procedure of sawing low-grade logs into standard lumber and then converting this standard lumber into product parts. Instead, the SHOLO process is used to convert low-grade logs directly into product parts. In this report we describe the SHOLO process and give a specific example of one design of a SHOLO mill.

Although other applications of the SHOLO process are possible, it is designed for the production of pallet parts for standard warehouse pallets and the production of pulp chips from the material unsuited for pallet parts. The process appears to have a good profit potential where: (1) a plentiful supply of relatively low cost raw material is available; (2) a market exists for pallet parts and pulp chips; and (3) the number of sizes of pallet parts is limited to about eight or less.[1] The SHOLO process uses factory grade 3 or poorer quality logs. The production of both pallet parts and pulp chips means that most of the raw material is converted into salable products, and little waste remains.

[1] Reynolds, Hugh W. and Charles J. Gatchell. THE SHOLO PROCESS: RETURN ON INVESTMENT VS. MILL DESIGN. USDA Forest Serv. Res. Paper NE-187. NE, Forest Exp. Sta., Upper Darby, Pa. (In preparation for publication).

Our research indicates that the SHOLO process can be profitable as an independent operation. But, perhaps more important, the SHOLO process should be a welcome addition to any paper company's or pulp-chip producer's operation. Also, the process might be applied by timber holders interested in reforestation of low-grade hardwood stands.

The SHOLO process is used to produce parts for the standard sized warehouse pallets (fig. 1). This pallet is made with three different sizes of parts. The stringers are 48 inches long and 2 by 4 inches in cross section. The deck boards are 40 inches long and either 1 by 4 or 1 by 6 inches in cross section.

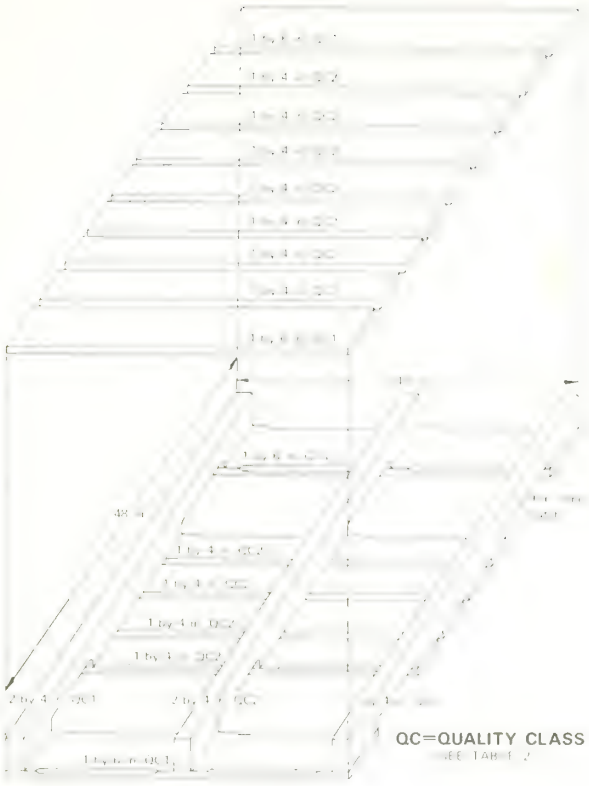
The concept behind the SHOLO process for the production of pallet parts is relatively simple. Selectively buck long, low-grade logs into SHOLO logs[2] of higher quality. Convert all round residue from the bucking operation to pulp chips. Live-saw the SHOLO logs to boards, selectively rip the boards to the proper widths, and end trim the boards to the required lengths. Convert all slabs and edgings to pulp chips. Sort the pallet parts into one of two quality classes. Package the parts on pallets and ship.

Our pilot-plant tests have shown that the actual production of pallet parts is also simple. It is simple because there are only four major decision points in the entire process, and the range of decisions is quite limited at each of these points. First, the SHOLO log maker decides whether a section of the long, low-grade log is good enough to become a SHOLO log. Second, the head sawyer decides which is the poorest face of the SHOLO log and always places the log on the saw carriage with this face towards him. Third, the ripsaw operator must decide whether a 4- or 6-inch wide cutting is to be made and whether additional cuttings are contained within each board. Fourth, the trimsaw operator must decide into which of two quality classes each pallet part falls.

To determine whether a section of long log is good enough, the SHOLO log specifications for pallet part production are fol-

[2]A SHOLO log is not "just" a short log. It is a short log of a minimum length and quality (see the specifications, table 1). The SHOLO mill can work with any low-grade log from 8 feet to tree length, as long as the minimum diameter of the small end is 8 inches.

Figure 1.—48- by 40-inch standard warehouse pallet.



lowed (table 1). The length of the SHOLO log is equal to the length of the pallet part plus end trim. For 48-inch-long parts, 52-inch SHOLO logs are bucked. For 40-inch-long parts, 44-inch SHOLO logs are bucked. For a balanced production of pallet parts, three 44-inch SHOLO logs are bucked for each 52-inch SHOLO log.

To maintain a reasonable production rate, the long log is not turned before bucking. The top face of the long log is examined for a rejection-type defect. If none is present, a SHOLO log is bucked. If there is a rejection-type defect on the top face, the front and back faces are inspected. Rejection-type defects in either of these faces means the SHOLO log cannot be bucked. Because the long log is not turned during the bucking operation, occasionally an unacceptable SHOLO log will be cut. These logs are treated as round residue and are converted into pulp chips.

Table 1.—*SHOLO log specifications for production of pallet parts*

Diameter	8 to 18 inches (small end), measured inside bark.
Length	44 inches, ± 2; or 52 inches, ± 2 inches.
Frequency	There shall be three 44-inch SHOLO logs made for each 52-inch SHOLO log.
Log faces	The top one-quarter of the log will be the top face, the bottom one-quarter will be the bottom face, and the other two faces will be the front and back faces.
Defects	A surface defect covering less than one-half the width of each face of the SHOLO log will be ignored provided that no indication of heart rot is found. A surface defect covering more than one-half of each face of the SHOLO log or a smaller defect that indicates heart rot will be considered as rejection-type defects. The SHOLO logs will be inspected for defects on the surface only.
Configuration	Rejection-type defects on adjacent faces will not be permitted. Rejection-type defects on opposite faces will be permitted. Only one such defect per face will be permitted. Both ends must be square to the log and flat. Taper exceeding one-fourth of the SHOLO log diameter (small end) will not be allowed.

The ripsaw operator must decide whether one or more cuttings are available within a board. The trimsaw operator must decide into which of two quality classes a pallet part falls. Both operators base their decisions on two pallet-part quality class specifications (table 2). While the trimsaw operator must base his decisions on a thorough knowledge of both classes, the ripsaw operator is concerned only with ripping out parts that meet or exceed the requirements of the lower grade of parts (quality class 2).

Separating the pallet parts into two quality classes is a new concept developed by Dr. Walter B. Wallin of the Forest Products Marketing Laboratory. During an extensive study of damage to pallets in industrial use, Dr. Wallin observed that the major damage occurred to the outside stringers and to the edge deckboards.

Table 2.—*Specifications for pallet parts from the SHOLO process*

	Quality class 1 ..... High strength parts to be used in the impact areas of the pallet—the pallet sides and ends.	Quality class 2 ... Normal strength parts to be used in the interior of the pallet.
Intergrown knot size	Not more than one-fourth the width of the part.	Not more than one-half the width of the part.
Number of knots	No more than one knot per 12 inches of length.	No more than one knot per 8 inches of length.
Knot location	No knots in nailing areas or edges of deckboards. No knots in the 2-inch faces of the stringers.	Sound knots no more than one-fourth the width of the part allowed in the nailing area or on edges of the deckboards or in the 2-inch faces of the stringers.
Holes and unsound knot size	No more than one-eighth the width of the part.	No more than one-fourth the width of the part.
Wane	Not permitted.	Total wane no more than one-fourth the length, one-sixth the width, or one-half the thickness. Two-by-four stringers can have wane no more than one-fourth the thickness.
Decay	Not permitted.	Not permitted.
Splits	Not permitted.	No more than 2 inches long.
Shakes	Not permitted.	No more than 2 inches long.
Cross grain	1 inch in 12 inches minimum.	1 inch in 8 inches minimum.
Dimensions	*Nominal* *Actual*	
Thickness	1 in. 13/16, ± 1/32, planed two sides	Same as class 1
	2 in. 1-5/8, ± 1/16, planed two sides	Same as class 1
Width	4 in. 3-5/8, ± 1/16, ripped two sides	Same as class 1
	6 in. 5-5/8, ± 1/16, ripped two sides	Same as class 1
Moisture content	Green as sawed.	Same as class 1
Species	NWPCA class C, dense hardwoods: oak, beech, birch, hickory, and hard maple.	Same as class 1

[1] Anonymous. SPECIFICATIONS AND GRADES FOR HARDWOOD WAREHOUSE, PERMANENT, OR RETURNABLE PALLETS. National Wooden Pallet and Container Association. 1619 Massachusetts Avenue, NW., Washington, D. C. 1962.

By placing the best available material at these locations, a better and longer-lived pallet can be produced. The quality classes of table 2 resulted from his investigations.

All other production decisions are predetermined. For example, the 52-inch SHOLO logs are always live sawed into 2-inch-thick boards. These boards always are ripped to 4-inch-wide cuttings and trimmed to 48 inches in length. The 44-inch logs are always live sawed to 1-inch thick boards. These boards are ripped to either 4- or 6-inch width, and are always trimmed to 40 inches in length. Because of the simplicity of the SHOLO process—as compared to regular hardwood sawmilling—workers are easily trained. Skilled mechanics are required, but highly trained sawyers and lumber graders are not.

FACTORS AFFECTING SHOLO MILL DESIGN

The SHOLO mill concept is based on the use of factory grade 3 and lower quality logs. However, because of the variability within this grade, the specific design of the mill can vary and depends upon the nature of the logs used.

The quality of the raw material must be carefully determined. The most reliable and least expensive method for doing this is a pilot-plant test. Quality is measured in terms of the amount of SHOLO logs that can be bucked from a representative sample of long logs. This factor, termed the long-log potential, is determined on a weight basis. The long-log potential is obtained by dividing the total weight of SHOLO logs by the total weight of the representative sample of long logs.

How the long-log potential influences the SHOLO mill design can be understood by considering four samples of logs that we evaluated (table 3). Samples 1, 2, and 3 were all poor factory grade 3 or local-use logs. Sample 4, which averaged out to be factory grade 3, had a range of grades from factory grade 2 to local-use. About half of the factory grade 3 logs in sample 4 were below 11 inches in diameter. Had they been larger in diameter, they would have been factory grade 2 logs.

Table 3.—*Comparison of low-grade red oak log quality from two different locations*

Sample number	Log source	No. of logs	Log description	Long log potential[1] (percent)
1	Eastern Tenn. (reforestation project)	75	Random length (8 to 21 feet), poor factory grade 3 and local-use logs, 8 to 18 inches in diameter.	56
2	Eastern Tenn. (reforestation project)	121	Twenty-one feet long, lowest quality pulp logs, 8 to 18 inches in diameter.	58
3	Southern West Virginia strip-mine site	58	Random length (7 to 16 feet) top logs, poor factory grade 3 and local-use—much taper, 8 to 17 inches in diameter.	94
4	Southern West Virginia strip-mine site	28	Random length (7 to 16 feet). Average grade, factory grade 3; grade range, factory grade 2 to local-use. Eight to 14 inches in diameter.	87

[1]Long log potential = $\frac{\text{total SHOLO log weight}}{\text{total long log weight}} \times 100$

The differences between the designs of the SHOLO mill needed for samples 1 and 2 and for samples 3 and 4 are considerable. Only about half of the long logs (by weight) in samples 1 and 2 could be bucked into SHOLO logs. This means that the mill must be designed to include a whole-log chipper to convert the remainder of the long logs to pulp chips. This piece of equipment, with screens, costs about $14,000 and requires a full-time operator. A log splitter saw, costing about $8,000 is also necessary to convert the large diameter pieces of round residue into pieces small enough to fit into the whole-log chipper.

On the other hand, the SHOLO mill for samples 3 and 4, will not need a whole-log chipper or a log-splitter saw. In these samples, about 90 percent of the long logs (by weight) could be converted to SHOLO logs. The slabs, edgings, and end trim-

mings could be converted to chips by a wastewood chipper after the end-trim operation. A suitable wastewood chipper, including screens, costs about $8,500. The wastewood chipper does not require an operator and represents a savings in capital investment of around $13,500.

Another important difference between the requirements for the SHOLO mill results from differences in long-log potential. For samples 3 and 4, fewer logs (by about one-third) are required for the same output of pallet parts. This means a reduction in the output of pulp chips and thus, a lower level of activity in the mill yard. Less long-log storage capacity, less debarking capacity, and fewer bucking cuts are some of the operational benefits. Assuming the price of logs to be about the same for all samples, the SHOLO mill log costs for samples 3 and 4 will be less, because fewer logs are needed.

EXAMPLE OF A SHOLO MILL

In the following example, we describe a SHOLO mill design that we consider suitable for converting raw material, such as was found in samples 1 and 2 of table 3, into parts for standard warehouse pallets and pulp chips. This mill will require a daily input of around 200 tons (70 cords) of long logs. The daily product output is parts for about 570 standard warehouse pallets and about 110 tons of pulp chips. At about 28 board feet per pallet, the parts output is about 16,000 board feet per day. The mill yard will operate 5 days per week on a single shift. The parts plant will also operate 5 days a week, but on a double shift.

In this example, we assume that pallet parts will be shipped to a pallet assembly plant. There are cost advantages to shipping parts rather than assembled pallets.

In setting up any production process, there are few hard and fast rules. You may well decide that greater efficiency can be realized by one or more modifications to the process in this example. This is as it should be. Our attempt is to describe one

realistic way to convert low-grade hardwood logs directly into pallet parts.

The Mill Yard

Log purchasing, storing, debarking, bucking, converting residue to pulp chips, and disposing of waste are performed in the mill yard. The flow chart for the mill yard is shown in figure 2. The index numbers on the flow chart and in the text correspond to the items listed in table 4.

Poor factory grade 3 and lower grade long logs are purchased by weight (1). A forklift truck (2) brings the long logs either to the storage yard (3), or to the infeed log deck (4a). Bark is removed with a ring debarker (5). A debarking capacity of about 14,000 lineal feet per day is required. Waste from the

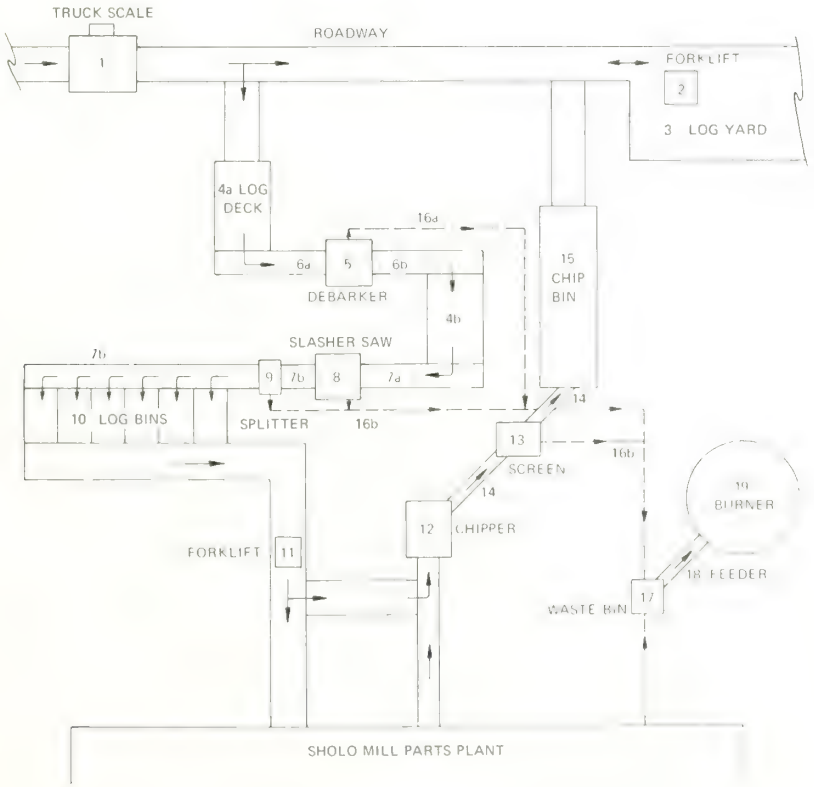


Figure 2.—Flow chart of SHOLO mill yard.

Table 4.—*Capital investment for SHOLO mill log yard*

Index No.	Description	Installed cost[1]
1	Truck scale/weight house	$ 20,000
2	Forklift truck for 21-foot-long logs	25,000
3	Log storage yard—road and fill	20,000
4a & 4b	Log deck—in and out @ $3,000	6,000
5	30-inch ring debarker and hog	25,000
6a & 6b	Debarker roll cases—in and out @ $2,000	4,000
7a & 7b	Slasher saw roll cases—in and out	4,000
8	Slasher saw, 54-inch	9,000
9	Retractable log splitter saw	8,000
10	SHOLO log bins	4,000
11	Forklift truck (4,000 pounds capacity)	6,500
12	48-inch chipper	10,000
13	Chipper screen	4,000
14	Chip bin conveyor	3,000
15	Chip bin	6,000
16a & 16b	Bark and sawdust conveyor to waste bin	5,000
17	Waste bin	3,500
18	Waste feeder, bin to burner	3,000
19	45-foot diameter waste burner, forced air control	18,000
	Total	$184,000

[1]1969 costs determined by averaging up to three estimates for each item.

debarker is conveyed (16a) to a waste bin (17) for temporary storage before burning (19).

The debarked logs are fed to a 54-inch-diameter slasher saw (8) and bucked into 44- and 52-inch SHOLO logs and into random-length round residue. Our research has shown that an average of about five bucking cuts will be made on logs that average 20 feet in length and have a long-log potential of about 60 percent. The average time per cut is about 7 seconds. A slasher saw can easily make these cuts, and the decisions required for making the cuts according to SHOLO log specifications are simple.

All residue is ripped in half by a retractable log-splitter saw (9). This step is necessary to insure that all residue will fit easily into the throat of the 48-inch chipper (12).

The 44- and 52-inch SHOLO logs and random length residue are dumped into temporary storage bins (10). A forklift truck (11) from the SHOLO mill parts plant carries the half-round residue to the chipper (12) when not transporting SHOLO logs into the plant. The pulp chips are screened (13) and conveyed (14) to the chip bin (15) for storage. Gravity loading of open-top chip trucks is used.

The SHOLO Parts Plant

The SHOLO logs are processed into finished, ready-to-use pallet parts, which are sorted for quality and packaged for shipping, in the SHOLO parts plant. The flow chart for the parts plant is shown in figure 3. The index numbers on the flow chart and in the text correspond to the items listed in table 5.

A forklift truck carries the SHOLO logs to the live deck of the 50-inch circular saw headrig (1). For production efficiency, the SHOLO logs are grouped according to length. The headrig operator live-saws a number of 52-inch-long SHOLO logs into 2-inch-thick boards and then saws a group of 44inch long logs into 1-inch-thick boards. As the boards come from the headrig, the operator sends them to conveyor (2) for the ripsaws. Slabs and dogboards are conveyed (3) back to the mill yard for conversion into pulp chips.

Ripping boards to widths for pallet parts is the most significant operation in the parts plant. This operation is performed on pairs of ripsaws. Each pair of ripsaws is in tandem and is controlled, with the aid of a memory device, by a single operator.

Just before arrival at the ripsaws, the boards are separated onto the board decks (4) though a gate controlled by the operator of the nearest pair of ripsaws (5a and 5b). After the operator makes his decision on the number and width of pallet part cuttings, he feeds the board to the first saw and sets the memory control for the second ripsaw. Coming out of the first saw, the edging to the left of the saw blade is dumped and conveyed (3) to the chipper. The board proceeds to the second ripsaw (5b).

If the memory control has been set for only one cutting, the board is ripped and all material to the right of the second saw

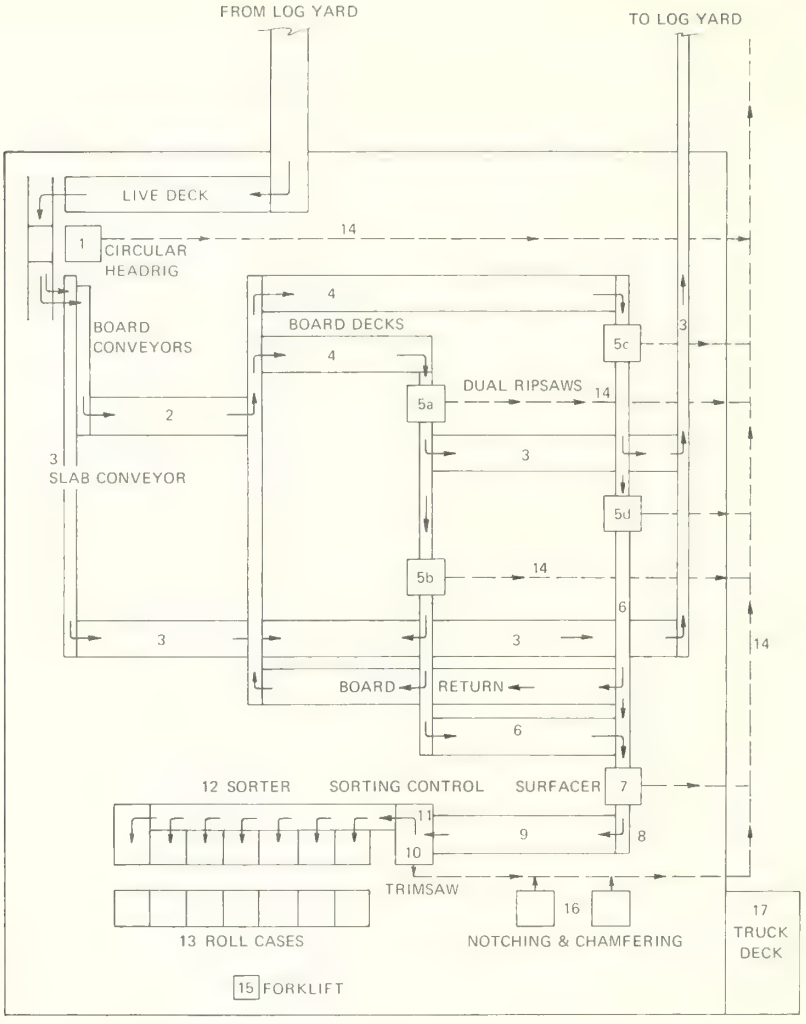


Figure 3.—Flow chart of SHOLO mill parts-plant.

blade is dumped and conveyed to the chipper. The pallet part is then conveyed (6) to the double surfacer (7). However, if another cutting is in the board, the memory control allows the cutting (pallet part) to the left of the saw blade in the second saw to be conveyed to the surfacer, but dumps the remainder of the board back onto the headrig-to-ripsaw conveyor system. The second pair of tandem ripsaws (5c and 5d) works in the same

manner. Cuttings from the ripsaws are conveyed (6) to the double surfacer (7) where they are planed to thickness.

After planing, the boards are conveyed (8) to the trimsaw live deck (9) and then moved to the trimsaw (10). The trimsaws are set for lengths of either 40 inches (for 1-inch-thick stock) or 48 inches (for 2-inch-thick stock). The trimmer operator uses memory controls (11) to sort the pallet parts into one of two quality

Table 5.—Capital investment for SHOLO mill parts plant and total cost for mill and yard

Index No.	Description	Installed cost[1]
1	50-inch circular headrig w/live deck	$ 28,000
2	Conveyor—headrig to ripsaws	2,000
3	Conveyors—slabs and edging to chipper	7,500
4	Ripsaw board live deck (2 required @ $3,000)	6,000
5	Dual ripsaws with controls and returns required (2 pair)	40,000
6	Conveyors—ripsaws to surfacer	2,000
7	Double surfacer	25,000
8	Conveyor—surfacer to trimmer live deck	1,000
9	Trimsaw live deck	3,000
10	Dual trimsaw	5,000
11	Sorting control to slot sorter	2,000
12	7-place slot sorter with bins	5,000
13	Dead roll cases	3,000
14	Sawdust and planer shavings conveyor to waste bin	7,500
15	Forklift truck (4,000 pounds capacity)	6,500
16	Notching and chamfering machines	15,000
17	Truck loading dock	15,000
18	Building 150 × 60 @ $10/sq. ft. (9,000 sq. ft.)	90,000
	Total	$263,500
	Total for mill log yard	$184,000
	Total for mill parts plant	263,500
	Millwright tools—saw and knife grinders	10,000
	Subtotal	$457,500
	Contingency—20 percent of above	92,500
	Total	$550,000

[1] 1969 costs determined by averaging up to three estimates per item.

classes and to separate pieces that may be below the quality class 2 specifications. The sorter (12) includes seven bins for temporary storage. Six of these bins are for the two quality classes and three sizes of parts. The seventh bin is for reject pieces. Rejects are transported by forklift to the conveyors (3) that carry slabs and edgings to the chipper. As bins fill up, they can be temporarily stored on dead rolls (13).

Finishing steps include notching (16) of all 2- by 4- by 48-inch stringers and chamfering (16) of some 1- by 4- by 40- or 1- by 6- by 40-inch deckboards. The number of boards to be chamfered will depend on the style of pallet to be made. All parts are color end coated according to quality class, piled on pallets, and strapped for shipment.

Manpower Requirements

The manpower required to operate the SHOLO mill is listed in table 6. The mill yard is run on a single shift and the parts plant is run on a double shift. A foreman is required on each shift. A millwright/maintenance man and a cleanup man can service all of the equipment and keep both the mill yard and the parts plant clean on a single shift basis.

In addition, six men are needed to operate the mill yard. A log buyer, purchasing on a weight basis, and a log forklift operator are needed to handle the long-log purchasing. A log debarker operator, a bucking operator for the slasher saw and log splitter, and an operator for the whole-log chipper are required to convert the long logs to SHOLO logs and the round residue to pulp chips. The sixth man is a forklift operator who transports SHOLO logs to the headrig and round residue to the whole-log chipper.

The parts plant is operated with seven men on the first shift and six men on the second shift. The extra man on the first shift is a notcher/chamfer operator who can process all necessary parts from both shifts. Two ripsaw operators are required to keep up with the output of the headrig operator. A trimsaw/sorter operator and two parts stacker/truck loaders complete the crew. Each of these last two men must be able to operate a forklift truck as part of the truck loading operation. They will end-coat the pallet

Table 6.—*Manpower requirements*

Location	Job description	Number of men	
		First shift	Second Shift
General	Foreman	1	1
	Millwright/ maintenance	1	0
	Cleanup	1	0
	Subtotal	3	1
Mill yard	Scaler/log buyer	1	0
	Long log forklift operator	1	0
	Debarker operator	1	0
	Bucking operator	1	0
	Whole log chipper operator	1	0
	SHOLO log/round residue forklift driver	1	0
	Subtotal	6	0
Parts plant	Headrig sawyer	1	1
	Ripsaw operator	2	2
	Trimsaw/sorter operator	1	1
	Parts stacker/truck loader	2	2
	Notcher/chamfer operator	1	0
	Subtotal	7	6
	Total	16	7

part according to quality, bring parts to the notching and chamfering operation, and load and strap the parts on pallets for shipment.

We recognize that modifications in the design of the SHOLO mill, local union requirements, or other factors can easily change the number of men needed. We believe, however, that we have presented a reasonable minimum for a mill of the particular design we have described.

SHOLO Mill Costs

The expected capital investment for the entire SHOLO mill is itemized in tables 4 and 5 and totalled at the bottom of table 5. All costs are based on prices available in late 1969. Costs were determined by averaging up to three estimates per item. The total cost of the mill yard, the parts plant, and all of the equipment is about $458,000. Since all values given are estimates, a 20 percent contingency fund of $92,500 is listed. This fund could be used to cover a slight rise in the prices quoted and to provide a margin for unforeseen increases in construction costs. The total cost of the SHOLO mill described is about $550,000.

■

THE FOREST SERVICE of the U. S. Department of Agriculture is dedicated to the principle of multiple use management of the Nation's forest resources for sustained yields of wood, water, forage, wildlife, and recreation. Through forestry research, cooperation with the States and private forest owners, and management of the National Forests and National Grasslands, it strives — as directed by Congress — to provide increasingly greater service to a growing Nation.

The Culture Of
INDIAN TOBACCO
(Lobelia inflata L.)

by Arnold Krochmal
and Leon Wilken

U.S.D.A. FORST SERVICE RESEARCH PAPER NE-181
1970

NORTHEASTERN FOREST EXPERIMENT STATION, UPPER DARBY, PA.
FOREST SERVICE, U. S. DEPARTMENT OF AGRICULTURE
RICHARD D. LANE, DIRECTOR

The Authors

ARNOLD KROCHMAL was graduated from North Carolina State College in 1942; he received his master's degree in 1951 and his Ph.D. in 1952 from Cornell University in economic botany, with a minor in plant physiology. As a Fulbright professor he has worked in Greece, and in Afghanistan, Honduras, and the U.S. Virgin Islands. He has also served as a consultant in Thailand, the Dominican Republic, British Virgin Islands, Jamaica, Monserrat, and Surinam. In 1966 he joined the USDA Forest Service's Northeastern Forest Experiment Station as project leader and principal economic botanist in charge of the Station's timber-related crops research program, located at Berea, Kentucky.

LEON WILKEN was graduated cum laude from the College of Pharmacy at Loyola University in New Orleans in 1951; he received his master's degree in 1953 and his Ph.D. in 1963 from the University of Texas, Austin. From 1953 to 1963 he was employed as special instructor in pharmacy at the University of Texas; from 1963 to the present he has served as associate professor of pharmaceutics at the School of Pharmacy at Auburn University, Auburn, Alabama. His current research involves the study of plants and folk medicine with active constituents and therapeutic value.

MANUSCRIPT RECEIVED FOR PUBLICATION 16 JULY 1970.

The Culture Of
INDIAN TOBACCO
(Lobelia inflata L.)

Figure 1.—A mature wild plant of *Lobelia inflata* L. Flower at lower right.

INDIAN TOBACCO (*Lobelia inflata* L.) is the source of an alkaloid (lobeline) that is used in anti-smoking preparations. Because of a brisk market demand for lobelia—and a decline in the harvesting of wild plants—we have studied how to grow this wild Appalachian annual (fig. 1) as a row crop under cultivation.

Our studies, begun in 1967, have continued through 1970. We have learned how to germinate the seed and grow young plants for setting out in the field, and how to care for them until harvest (fig. 2).

Figure 2.—Under cultivation, *Lobelia inflata* plants become bushier and larger, and yield far more marketable plant material.

The seeds (fig. 3), which are smaller than tobacco seed, were harvested from wild plants in a wide range of habitats such as abandoned fields, open glades in hardwood forests, and old logging roads. We have found the plants growing on soils with pH's ranging from 4.1 to 5.8, and we believe they will thrive best on acid soils.

Seed harvest can begin about July and continue through August. It is easiest and most practical to harvest entire plants with seed capsules (fig. 1), and to remove the capsules indoors to minimize loss of seed. The plants can be air-dried for a week to 10 days; then the capsules will open easily, and seed removal is simple. We have used a 60-mesh screen to separate the seed from chaff. The seed are stored over winter at room temperature in mason

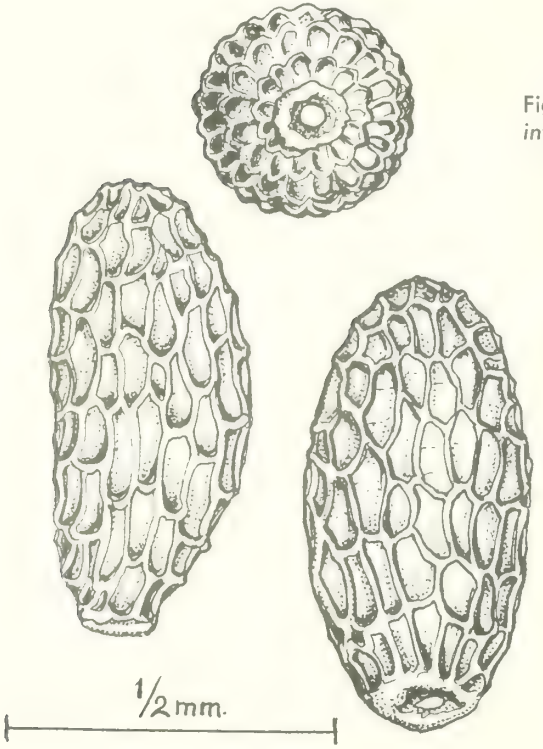


Figure 3.—Seed of *Lobelia inflata*.

Figure 4.—A plastic seed flat ready for seeding.

jars with cheesecloth covers. Planting is done about January or February.

Seed flats are filled with a potting mix (1/3 sand, 1/3 soil, 1/3 peat), covered with cheesecloth (fig. 4); and the seeds are scattered over the top of the cheesecloth. Bottom watering is essential to keep the tiny seeds from washing together into clumps. The flats can be set in a shallow tray for this purpose (fig. 5).

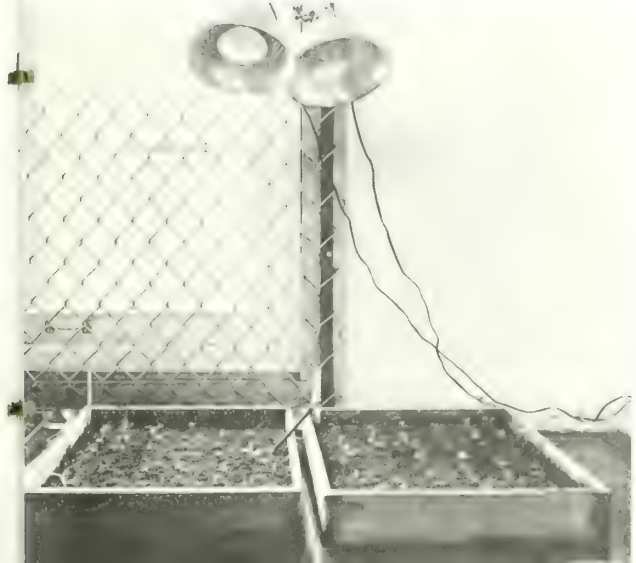


Figure 5.—Two reflectors with incandescent bulbs provide a continuous source of supplemental light. The flats are in a watering tray.

Figure 6. — Germinating lobelia plants are minute. (Photo by James Keen, *Louisville Times*.)

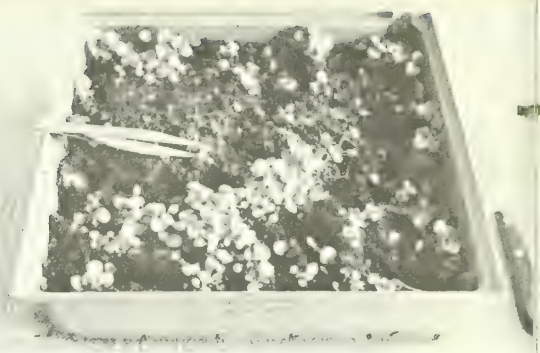


Figure 7.—When the plants are big enough for first transplanting, the cheesecloth has decayed and removing the plants is easy.

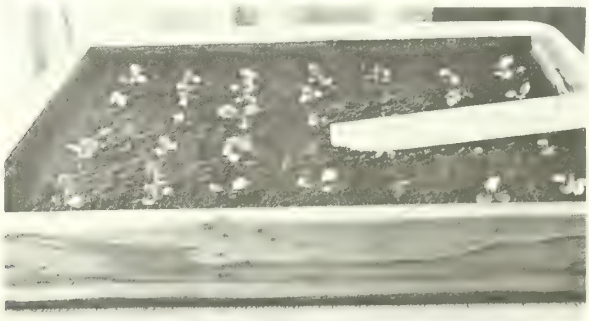


Figure 8.—A larger flat is useful for the larger plants after the first transplanting.

Light in the red end of the spectrum is required for germination. This can be provided by the use of incandescent household light bulbs. A continuous light source of two 200-watt bulbs, in reflectors, or one 200-watt and one 100-watt bulb (fig. 5), can be used to supplement or replace daylight. These lights can be placed about 2½ feet above the seed flats. Each set of 2 reflectors will serve 4 to 8 flats, depending on the size of the flats. Any suitable room or warm area with some sun exposure will do.

Germination takes place a week or 10 days after planting (fig. 6). After 6 to 8 weeks of growth, when some of the plants are about 1 to 1½ inches tall (fig. 7), they should be transplanted into seed flats at a spacing of 2 inches by 2 inches. These flats are filled with potting mix covered with 1 inch of peat moss (fig. 8).

Three to 5 weeks later, when the plants are about 2 inches tall, they are ready for field planting. We suggest small plantings of 1/8 acre for growers until they gain experience in handling this plant.

The distance between rows will depend on the implements to be used for weed control, but the rows should be at least 18 inches apart. In Madison County, Kentucky, we have grown crops on silty clay loam with a heavy clay hardpan 24 inches below the surface and with poor drainage.

If flowering begins within a month of planting, removal of the flowers is suggested to increase initial vegetative growth. Weeds should be kept under control during the growing season; and as harvest time approaches, clear cultivation is required to facilitate harvesting while eliminating contaminating weed plants. No need for insecticides or fungicides has been noted.

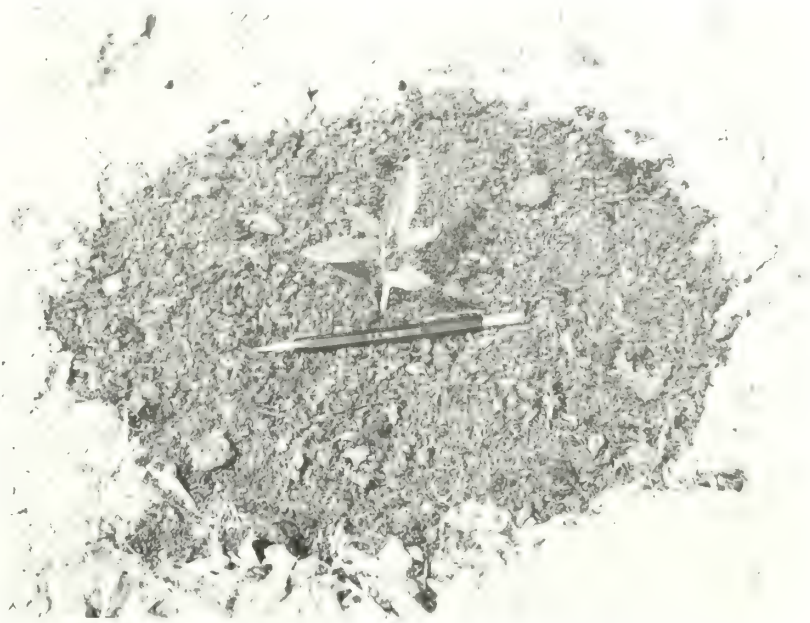


Figure 9.—A young plant in a field. A ring of peat moss was placed around it at planting time to help conserve moisture.

Avoid the use of herbicides and the risk of contaminating the crop, because no information is available about the effects of various herbicides on lobelia.

In transplanting, a small amount of peat moss can be put into the planting hole, and handful around the base of the plant (fig. 9) to conserve moisture. As the plants are set, they should be watered. Watering should be frequent the first 2 weeks—daily or on alternate days—then as needed, depending on rainfall. No need for fertilizer has been established.

HARVESTING

Harvesting for maximum lobeline requires the plants to be cut at ground level when they are in full bloom, or at the time of early seed set in the middle of August or early September. At these times, plant yields will be highest. Harvesting can be done by knife, sickle, or mowing bar. The plants can be laid in windows until enough are cut to move to the drying area. Because this is a very new kind of crop, we have limited data for predicting yields.

DRYING

Harvested plants should go under cover as soon as practical to reduce possible rain damage and decay. Harvested plants can be spread out on newspaper several layers deep for about a week, or can be dried in a simple home-made drying box.

An inexpensive dryer using an electric forced-air heater can be built easily (fig. 10). The drying plants can be laid five or six layers deep in the trays.

When the plants are crackling dry, they can be bundled into burlap bales for shipment to the buyer. No standard weight or size of package has been established.

A partial list of buyers of botanicals is given in table 1.

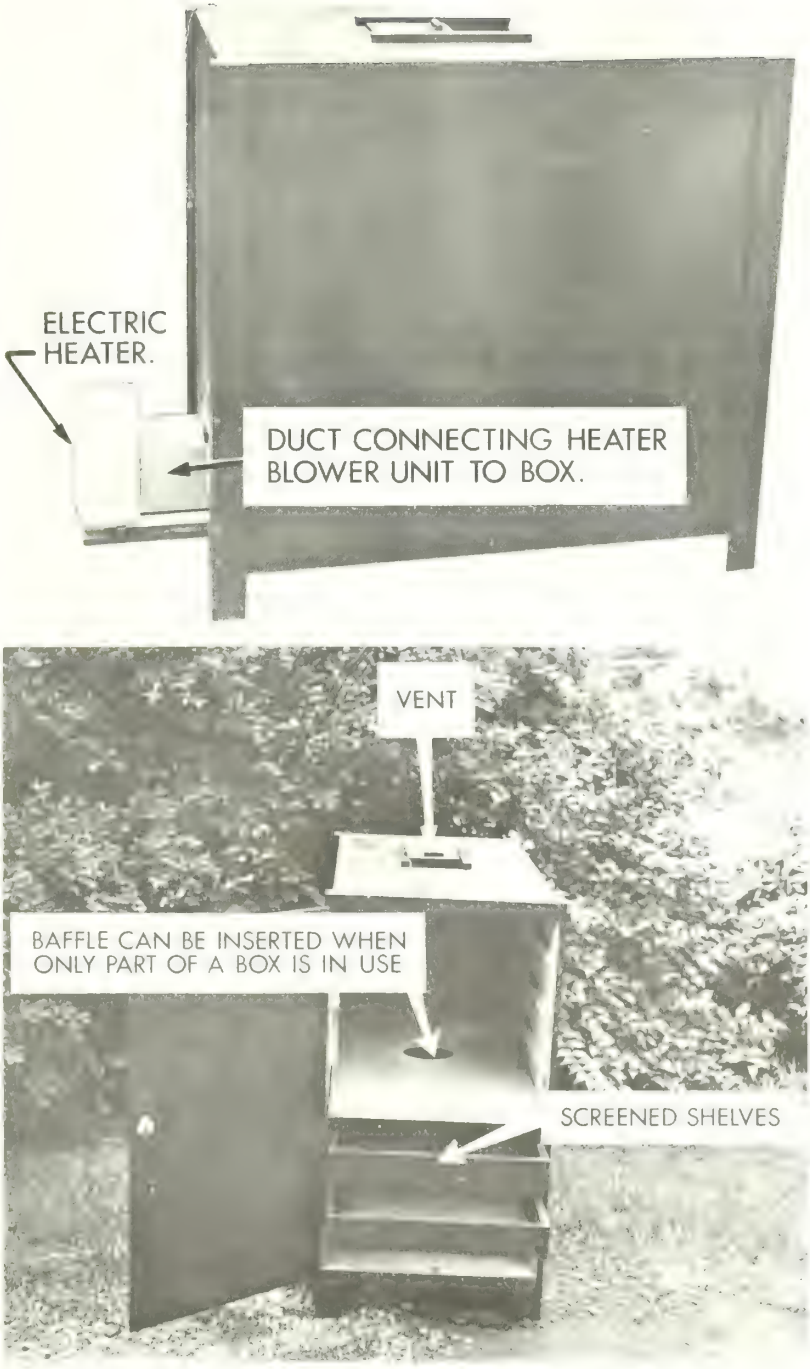

ELECTRIC HEATER.
DUCT CONNECTING HEATER BLOWER UNIT TO BOX.
VENT
BAFFLE CAN BE INSERTED WHEN ONLY PART OF A BOX IS IN USE
SCREENED SHELVES

Figure 10.—Side (above) and front (below) views of a simple drying box, using a forced-air electric space heater.

Table 1.—*Names and addresses of buying houses**

Name	Address
PURCHASERS OF BOTANICALS	
Blue Ridge Drug Company	Box 234, West. Jefferson, N.C. 28694
Coeburn Produce Company	Second and Grand Streets, Coeburn, Va. 24230
C. R. Graybeal	Roan Mountain, Tenn. 27687
F. C. Taylor Fur Company	227 E. Market Street, Louisville, Ky. 40202
Greer & Greer	Box 307, Princeton, W. Va. 24740
Greer Drug & Chemical Company	Box 800, Lenoir, N.C. 28645
Nature's Herb Company	281 Ellis Street, San Francisco, Calif. 90025
Old Fashioned Herb Company	581 N. Lake Avenue, Los Angeles, Calif. 90026
Smoky Mountain Drug Company	Box 2, 935 Shelby Street, Bristol, Tenn. 37620
Wilcox Drug Company	Box 391, Boone, N.C. 28620
Wilcox Drug Company, Inc.	Box 470, Pikeville, Ky. 41501
IMPORTERS THAT BUY, SELL, AND PROCESS BOTANICALS	
Hathaway Allied Products	2024 Westgate Avenue, Los Angeles, Calif. 90025
S. B. Penick & Company	100 Church Street, New York, N.Y. 10007
VENDORS OF DRUG AND HERB SEED AND OTHER PROPAGATING MATERIALS	
Gardens of the Blue Ridge	Ashford, N.C. 28603
Harry E. Saier	Dimondale, Michigan 48821
Indiana Botanic Gardens	Box 5, Hammond, Ind. 26325

*These firms are mentioned for information only, and this mention should not be considered as an endorsement or recommendation by the U. S. Department of Agriculture or the Forest Service.

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LAND for RECREATION:

a look at LEASING in New York

UNIVERSITY
JUN 28 1971
TECH. & AGR.

by James C. Whittaker
and Herbert E. Echelberger

U.S.D.A. FOREST SERVICE RESEARCH PAPER NE-182
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NORTHEASTERN FOREST EXPERIMENT STATION, UPPER DARBY, PA.
FOREST SERVICE, U.S. DEPARTMENT OF AGRICULTURE
RICHARD D. LANE, DIRECTOR

THE AUTHORS

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HERBERT E. ECHELBERGER is a research forester at the Northeastern Forest Experiment Station's recreation research unit in Syracuse, N. Y. Much of his work is in cooperation with the New York State College of Forestry at Syracuse University. He received his bachelor's and master's degrees in forestry and forest recreation from Southern Illinois University.

MANUSCRIPT SUBMITTED FOR PUBLICATION 24 JUNE 1970.

LEASING MAY BE THE ANSWER

WOULD YOU LIKE to have a place in the country, though you can't afford the price of the real estate? Would your club like some land to develop facilities for recreational outings, though your club treasury isn't big enough to buy the land? Do you want to develop a campground business or perhaps a shooting preserve, but find that interest rates on the investment are prohibitive?

Leasing may be the answer to your problem. Many individuals and groups have bypassed land-ownership requirements by leasing suitable land from private landowners.

As part of its research to help woodland owners benefit from the recreation potential of their land, the USDA Forest Service recently conducted a survey of individuals and groups in New York State who lease private land for recreation purposes. Similar studies have been conducted in other Northeastern States (*1, 2, 3*).

In November 1968, 343 questionnaires were sent out to groups and individuals believed to be leasing private land for recreation. Of the 124 lessees who responded to the survey, the majority (102) were hunting or shooting organizations with an average membership of 47 people. Eight of the lessees represented organizations

interested in group or family outing activities; average membership in these groups was 67 people. The remaining 14 lessees were individuals or partnerships who leased lands for personal use or to operate a commercial recreation enterprise.

Who Leases What?

All together, the 124 respondents owned and leased a total of 313,484 acres of land and water; about 72 percent of the total was leased. Of the leased land, about 72 percent was forest-covered, 21 percent was open land, 5 percent was in ponds and lakes, and 2 percent was in other types of land use (table 1).

Hunting and shooting organizations leased about 83 percent of the total leased area, group and family outing organizations leased about 14 percent, and the individual or partnership leases accounted for 3 percent.

Most of the leases were for less than 500 acres, but leased acreage ranged from 2 to 20,000 acres. Hunting and shooting organizations tended to lease more land per organization than the other types of lessees.

The duration of the leases varied from 1 to 99 years, but 54 percent renewed on a yearly basis. Areas leased for more than 1 year often contained buildings constructed by the lessee.

Table 1.—*Type and acreages of resources leased, by type of lessee*

Resource	Type of lessee			
	Hunting-shooting organizations	Group or family outing organizations	Individuals or partners	Total
Ponds or lakes[1]	685	[2] 10,002	5	10,692
Forest covered[3]	140,365	20,559	3,197	164,121
Open land[4]	43,809	150	3,890	47,849
Other[5]	3,750	—	200	3,950
Total	188,609	30,711	7,292	226,612

[1] Surface acres of ponds or lakes as reported by lessees.
[2] One lessee reported that half of the 20,000 acres his club leased consisted of ponds and lakes.
[3] Acres of land that are forest covered as reported by lessees.
[4] Acres of land considered by lessees to be open land.
[5] Generally land with buildings and other man-made structures.

Figure 1.—A little water and a lot of land, both open and forested, describes the resources leased from New York State landowners.

How Do They Use It?

The lessees offered every form of activity listed on the questionnaire, plus several that were not listed, such as snowmobiling and trapping. The user-days reported in each of the 13 listed activities were as follows:

Activity	*Percent*
Hunting, small game	38.5
Hunting, big game	22.7
Fishing	13.4
Shooting	9.8
Hiking	4.8
Camping	3.3
Swimming	1.9
Boating	1.7
Picnicking	1.1
Archery	.7
Canoeing	.4
Riding	.2
Other	1.5

Hunting, fishing, and shooting accounted for 84 percent of the total user-days spent on these activities (fig. 2).

Of the 124 lessees who responded, 110 were representatives of various organizations. The organizations reported a total membership of 5,376 people, who participated in 107,577 user-days, or about 20 user-days per member. (One user-day equals one person

Figure 2.—Hunting for small and big game, fishing, and target shooting accounted for more than four-fifths of the user-days reported by lessees.

using leased land for any part of a day.) The hunting and shooting organizations reported an average of 16 user-days per member. The group and family outing organizations reported 57 user-days per member.

The 110 organizations owned and leased 304,486 acres, or about 57 acres per member. Hunting-shooting organizations made available 40 acres per member.

How Much Do They Pay?

Respondents indicated that their annual leasing costs ranged from zero to $10 per acre. There were 47 lessees who did not pay anything for their leased land. They generally reimbursed the lessor with some other kind of payment such as practicing conservation measures or allowing the lessor free use of the developed recreational facilities.

Since a quantitative value cannot be assigned to this kind of payment, lessees paying zero rental rates were not included in our calculations. Other lessees made partial payments for the land they leased and allowed the landowner free or reduced-price use of the developed facilities. Lessees making partial payments were included in the calculations presented below.

Open land provided lessors with the best annual rate of return, $0.74 per acre (table 2); but half of this open land was intermixed with forests, ponds, and lakes. Forest-covered land provided the second highest annual rate of return to lessors—$0.36 per acre.

The lease rate paid per acre was related inversely to the amount of land leased; that is, the greater amount of land leased, the less the average rate of return to the lessor. In addition, those lessees who already owned property usually were willing to lease small tracts of adjacent land and pay a higher-than-average price. Nearly half of the lessees who leased under 500 acres owned property adjacent to their leased land, whereas only 9 percent of the lessees who leased over 5,000 acres owned adjacent land.

These two factors—low price per acre for large tracts, and high price per acre for small and often adjacent tracts—tend to bias to some extent the computed average lease rate per acre. For instance, more than half of the under-500-acre leases exceeded $0.40 per acre, but only 18 percent of the over-500-acre leases exceeded $0.40 per acre.

Two organizations in the group and family outing category leased lands that contained ponds or lakes. One lease was for 10,000 acres and cost $0.04 per acre. Another lease was for 2 acres but cost $0.33 per acre.

Remember that 47 respondents, or 38 percent of the lessees, did

Table 2.—Average annual lease rate paid per acre by each type of lessee for each type of resource, expressed as the ratio: total cost/total acreage

Kind of Resource	Type of lessee			
	Hunting-shooting organizations	Group or family outing organizations	Individuals or partners	All
Ponds or lakes	$0.38	$0.04**	$1.66*	$0.06
Forest covered	.37	.17	1.64	.36
Open land	.62	.43*	1.66	.74
Other	1.00*	—	—	1.00*
All	$0.53	$0.34	$1.65	$0.40

* Represents 1 respondent.
** Represents 2 respondents.

Figure 3.—POSTED and NO TRESPASSING signs are often put up by dues-paying members of private organizations who lease land from farmers and other landowners.

not pay anything for the land they leased. This large number of non-paying lessees suggests that not all landowners are interested in monetary returns from land they lease to outdoor recreationists. However, landowners do have better control over who uses their lands if those lands are leased to an organization. Furthermore, public relations between the landowner and surrounding communities are likely to be less strained when outdoor enthusiasts are confronted by fences and NO TRESPASSING signs erected by a club rather than by the landowner. (fig. 3).

Lease Rate Determination

Each lessee was asked what factors were important in determining the rate he was paying. The amount the landowner requested was mentioned most often as the most important factor that influenced the rate. But in some cases the landowner and prospective lessee negotiated until a rate was established that was acceptable to both parties. In these cases, lessees felt that landowners had a good idea what a fair price should be.

If the landowner was already a club member or wanted to become a member, an arrangement usually was made whereby the club leased the land for a nominal rate, and the landowner was given full and free membership privileges.

Another consideration that sometimes affected lease rates involved the intensity and kinds of conservation practices that the club intended to carry out on the leased land.

Reason for Leasing

When asked why they leased the specific area described in their contracts, 60 percent of the lessees gave these three reasons: ease of access; ownership of adjacent property; and abudance of the resources available for recreation opportunities on the leased land. Only 16 percent of the lessees mentioned monetary considerations as a reason for leasing. We have no way of telling how many potential lessees did *not* lease because the rates were too high.

Future Demand for Leased Land

Twenty-five lessees indicated that they would like to lease additional rural land—ranging from 5 to 20,000 acres and including individual tracts of 1 to 1,600 acres. They preferred lease durations from 1 to 20 years; the median was 5 years.

In aggregate, these 25 lessees represent a demand for 50,000 to 60,000 additional acres of rural land in New York State. If our survey contacted half the total number of lessees in New York, the potential demand for leasing could be more than 100,000 acres.

The land being sought for leasing need not be at the edge of metropolitan areas. The excellent road systems in New York and most other Northeastern States put virtually every major metropolitan center within a 2-hour drive of rural lands that might be leased for recreational purposes. These same roads put almost every landowner within easy reach of potential users.

Several other lessees indicated that they would like to lease additional land, but did not specify how many acres.

Increased overcrowding on public recreation areas in New York State will probably cause more individuals and organizations such as those represented in this survey to seek land for their own

private recreation use. But the price of real estate and high interest rates today prohibit purchase of needed resources. At the same time, landowners are feeling the pinch of increased taxes.

Land leasing would appear to be a possible alternative for recreationists and rural landowners to consider. Leasing can provide recreationists with private recreation facilities, while at the same time it can compensate landowners to help cover the costs of taxes and needed conservation improvements on their lands.

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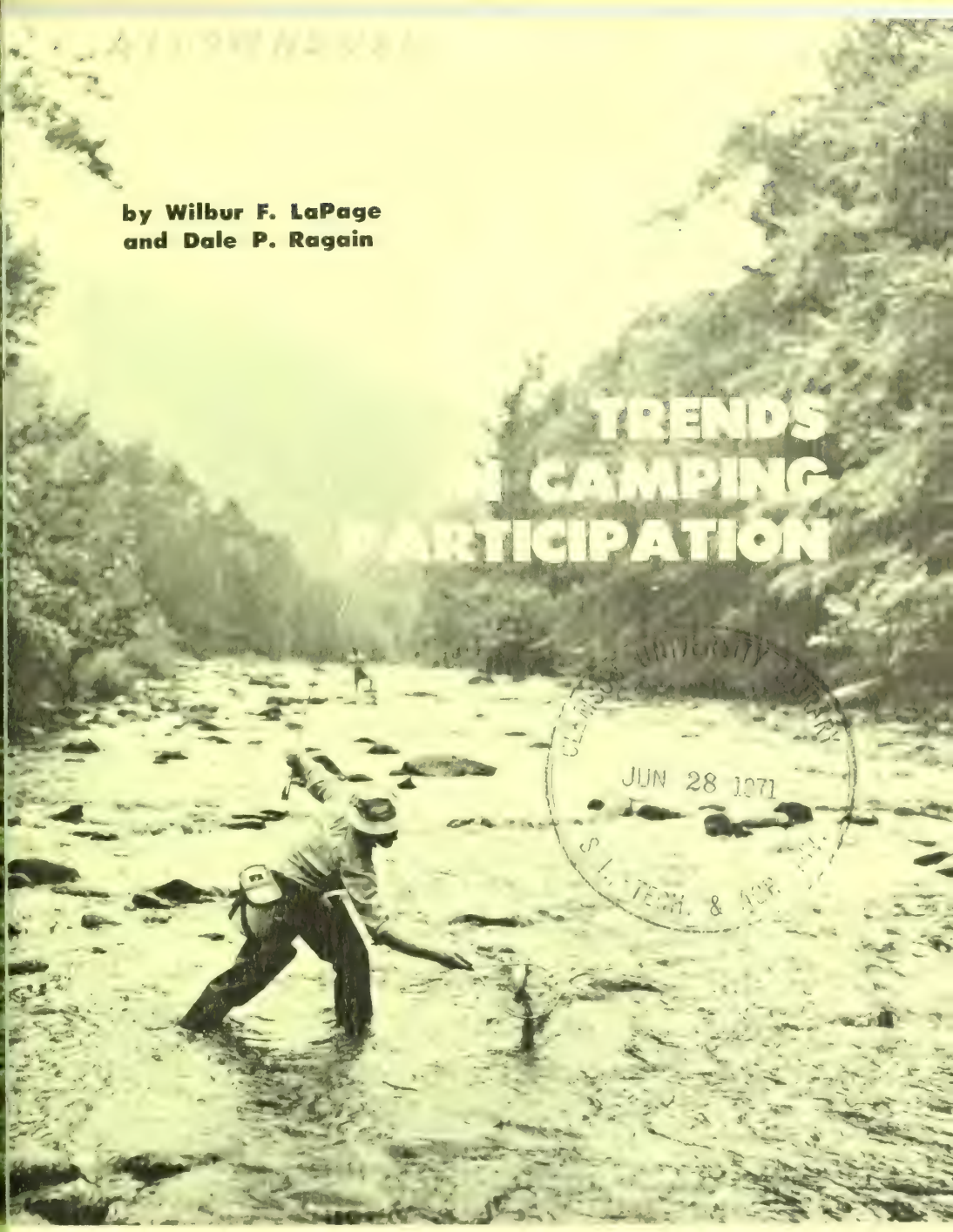
by Wilbur F. LaPage
and Dale P. Ragain

TRENDS IN CAMPING PARTICIPATION



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MORE CAMPERS—LESS CAMPING?

STUDIES OF outdoor-recreation demand invariably conclude that more people are recreating more often than ever before. Certainly the number of people on trails, in campgrounds, and on ski slopes is increasing. But the companion assertion that individuals are spending more time at outdoor recreation is questionable. After studying the camping trends of a panel of 565 campers for 5 years, we found that one-third of the campers reported a marked decline in their camping and other outdoor recreational activities. Only one-sixth of the panel reported increased camping.

This trend may be a concomitant of more people using outdoor resources, dwindling available supply, and reduced environmental attractiveness. If this is so, the impact upon resources and resource managers may be far greater than the simple increase in numbers of participants suggests.

The quality of outdoor recreational experiences has a great deal to do with styles of participation. Accepted styles are learned by novices through association with more skilled campers, skiers, etc. If, for example, experienced campers are not highly visible to help set style standards for new campers, we should expect to see distinct increases in vandalism, littering, and other undesirable forms of camping behavior.

THE STUDY

Several years ago the Northeastern Forest Experiment Station began a long-term study of per-capita camping participation. The objectives of the research were to identify campers with increasing or decreasing camping participation and to determine the causes of those trends.

The New England camper panel was composed of a group of 864 campers interviewed in 1964 and 1965 at 8 major public and private campgrounds throughout New England (fig. 1). The campgrounds were selected to represent the range of camping opportunities available in New England from primitive to highly developed, the range of physical features (coastal, mountains, lakes), and the range of ownership (state, federal, commercial). Occupied campsites within campgrounds and individual adult campers at each site were selected by using specially prepared random number tables. Each January for the past 5 years, the members of this panel received a brief questionnaire

Figure 1.—The public campgrounds sampled in 1964 were: (1) Baxter State Park, Maine; (2) Dolly Copp Campground, White Mountain National Forest, N. H.; (3) Nickerson State Park, Mass.; and (4) Rocky Neck State Park, Conn. The commercial campgrounds samples in 1965 were: (5) Hermit Island Campground, Bath, Me.; (6) Lakeside Pines Campground, North Bridgton, Me.; (7) Sweetwater Forest Campground, Brewster, Mas.; and (8) Eastern Slope Campground, North Conway, N. H.

concerning their past year's camping activity and other family changes that might influence camping participation such as changes in leisure interests, residence, family size, income, and expenditures. The results of the first 4 years of trend data are reported in this paper.

Throughout the study, panel response was excellent, never falling below 75 percent of the original sample. However, usable responses, those containing a full 4 years of data, were returned by slightly more than two-thirds of the panel members.

To determine whether selective drop-out had occurred during the study period, several comparisons were made between the composition of the original group of 864 campers and the final group of 565 campers who provided data for 4 consecutive years. Chi-square tests at the 1-percent significance level detected no differences in the composition of the two groups in terms of their camping behavior, camping attitudes, or demographic characteristics as measured at the beginning of this study. Behavioral items compared included median days of annual camping, the distribution of years of past camping experience, and the incidence of membership in camping clubs. The attitudinal check was made on the basis of percent agreement with a social definition of camping. And demographic checks were made on the basis of annual income distributions, age distributions, and the distribution of respondents from eight campgrounds where initial contacts were made (appendix, table 12).

FINDINGS

We found a decreasing trend in average annual recreational participation in this panel of family campers. The trend is surprising in view of the common criticism that panel studies tend to sensitize their subjects. That is, we expected that those campers having increasing participation might tend to dominate the panel over time, while those with declining camping interests would be increasingly likely to drop out of the study.

To evaluate individual participation trends it is necessary to arrive at a reasonable definition of "increasing" and "decreasing" participation. For example, is a 4-year participation sequence of

14, 21, 17, and 18 days an increasing, decreasing, or constant trend? We converted each individual participation sequence into a set of running averages and then arbitrarily set a ± 20-percent limit between the first and last running average figures as being indicative of a trend. Using this relatively strict definition, we classified the above example as constant participation; while a real increase has occurred, the running average procedure irons out the trend to less than a 20-percent change over the 4-year period.

On this basis, we conclude that a net decrease in participation has actually occurred because, of the 565 campers, those that had decreasing trends were almost double the number that had increasing trends:

Trend	*Percent of panel*
Increasing	17
Constant	50
Decreasing	33

A relatively small group of increasingly active campers was responsible for maintaining the total panel's continuity of participation (table 1).

The panel camped about 12,000 days annually and averaged about 21 days per family. With at least 12 weekends and 2 to 4 weeks of paid vacation available to most campers, an annual

Table 1.—*Mean annual camping days, and standard errors over a 4-year period, spent by campers with increasing, constant, and decreasing participation trends*

Trend group and group size	Average days camped			
	Year one[1]	Year two	Year three	Year four
Increasing (96)	21±1.7	21±1.8	35±2.5	41±2.8
Constant (284)	24± .9	25±1.0	24± .9	22±1.0
Decreasing (185)	19±1.0	15±1.1	7± .6	5± .5
Total (565)	22± .6	21± .8	20± .8	21± .8

[1]Because it took 2 years to assemble the complete panel, campgrounds 1 through 4 having been surveyed in 1964, and campgrounds 5 through 8 in 1965, it also takes 2 years for the total panel to complete 1 year of the trend. Year one reflects participation in 1964 for campers surveyed in that year plus participation in 1965 for campers initially contacted in that year. Similarly, year four represents participation in 1967 and 1968.

frequency of 21 days is certainly not crowding the camper's leisure time. To explain this lack of growth in average annual participation, we have examined the panel data in relation to several relevant theories about leisure behavior, including (1) life cycle and changing interests, (2) opportunity limitations, and (3) habit patterns and styles of participation.

Life Cycle Effects on Participation

The idea of a life-cycle influence upon leisure behavior suggests that people can be expected to display changing interests during different periods of their lives. For example, we might expect to find a high frequency of camping and related outdoor activities among young families. However, as the younger family members mature and develop diverse interests and as the family gradually disintegrates, the frequency of camping participation may decline. Also, we might expect to find a resurgence of camping participation beginning when children leave the home and continuing through retirement as parents have more time available to pursue their own leisure interests. Also, concurrent with these peaks and dips in family camping, we might expect to find compensating changes in other leisure activities and perhaps even a continuing expenditure for camping equipment as campers search for alternative ways of expressing interest in an activity that they no longer have time to pursue.

The age structure of the New England camper panel appeared to be normally distributed. About one-fourth of the parents were under the age of 35 when initially surveyed, nearly one-half were between 35 and 45, and another one-fourth were over 45. About one-third of each of these three age groups reported declining camping participation; only the over-45 age group showed a disproportionate number of campers having increasing participation (table 2). And we found a relatively uniform change in the average amount of camping participation by each of these 3 age groups (table 3).

Another way of looking at the concept of life-cycle is to examine participation frequencies by years of camping experience.

Table 2.—*Percentage of increasing, constant, and decreasing camping participation among three age groupings in the New England camper panel*

Trend	Age group		
	Under 35 (n=146)	35 to 45 (n=280)	Over 45 (n=139)
	Pct.	*Pct.*	*Pct.*
Increasing	17±3.0[1]	14±2.0	24±3.5
Constant	50±4.0	52±2.9	46±4.1
Decreasing	33±3.8	34±2.7	30±3.8

[1]The standard errors for percentages in this table are computed from the formula:

$$SE_p = \sqrt{\frac{p(1-p)}{n}}$$

(Ref. C .A. Moser. SURVEY METHODS AND SOCIAL INVESTIGATION, p. 71. Heinemann Press, 1958.)

Table 3.—*Percentage of total annual camping by three age-groups of campers, and mean days camped by each age group*

Age group	Year one	Year two	Year three	Year four
Under 35				
Total camping (Pct.)	24±1.7[1]	25±1.7	23±1.7	24±1.7
Average days	20±1.2	20±1.5	18±1.4	18±1.7
35 to 45				
Total camping (Pct.)	46±2.0	47±2.0	46±2.2	46±2.0
Average days	21± .8	20± .8	19±1.0	18±1.0
Over 45				
Total camping (Pct.)	30±1.9	28±1.8	31±1.8	30±1.8
Average days	26±1.5	24±1.5	25±1.8	24±1.8

[1]Refer to table 2 for explanation of standard error computation.

For example, are beginning campers, of any age group, increasing in their average annual participation while established campers, again of any age group, are declining? If so, this might tend to indicate that the content and appeal of camping itself regulates the stages of a camping life cycle rather than camper age and those attributes commonly associated with age such as family responsibility and changing resources of time and money.

To test this idea, we stratified the camper panel according to levels of camping experience at the start of the study as: *beginners,* having up to 2 years of camping experience (134 campers); *intermediates,* having 3 to 5 years of experience (174 campers); and *established campers,* having 6 or more years of experience (254 campers).

Four years later, the proportions of each of these three groups having declining camping participation was significantly greater only among the beginning campers:

Experience class 4 years ago	*Percent having declining camping*
Beginning campers	40
Intermediate campers	29
Established campers	32

The average number of days camped in each of these life-cycle stages, while different within each stage, did not significantly change over the past 4 years.

Apparently the stages of a life cycle, whether considered from the standpoint of camper age or relative camping experience, have little relationship to the volume, trend, or style of camping participation. Younger campers (under 35) were less likely to have been camping in a recreational vehicle during the year of their interview; but they purchased proportionately more recreational vehicles during the 4-year study period (table 4). Beginning

Table 4.—*Percent of campers initially using camping vehicles and subsequently purchasing camping vehicles, according to camper age groups and experience classes*

Life-cycle category	Initially used recreational vehicle	Purchased recreational vehicle
	Pct.	*Pct.*
Age class:		
Under 35	40	41
35 to 45	47	35
Over 45	51	36
Experience class:		
Beginners	51	46
Intermediates	40	32
Established	49	36

Table 5.—*Average number of outdoor recreational events and average number of recreational activities[1] participated in each year, other than camping, by panel members with increasing, constant, and decreasing camping trends*

Camping participation category	Year							
	One		Two		Three		Four	
	Events	Activities	Events	Activities	Events	Activities	Events	Activities
	No.	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*
Increasing	40	3	43	4	53	4	49	4
Constant	44	4	47	4	46	4	41	4
Decreasing	44	4	40	4	35	4	36	3

[1]Made up predominantly of swimming, hiking, picnicking, fishing, boating, hunting, and skiing.

campers had proportionately more vehicles initially and ultimately purchased more as well.

Campers in the past may have made a gradual transition from tents to recreational vehicles, but it is apparent that many of today's beginning campers start out with a recreational vehicle and buy bigger and better ones without ever camping in a tent.

The concept of life cycle implies a shifting of interests from camping toward some other activity. While our panel data does not include a complete inventory of leisure-time use, we were able to determine that, in the three experience groups, a reduction in camping was not compensated by an increase in some other outdoor recreation activity. In fact, increases and decreases in camping were commonly accompanied by increases or decreases in the camper's overall level of outdoor recreational involvement (table 5). Further, we found that those with increasing camping were more likely to hold onto all of their old activities and add new ones; whereas those with decreasing camping were more likely to drop old interests and not add new ones.

Opportunity Effects on Participation

The opportunity for an individual to engage in outdoor recreation can be limited in a variety of ways; most obviously by time and money. Available time and money are both extremely difficult to measure and are well beyond the scope of this study. However,

we can look at several different indices of these two limiting factors such as income, family size, camping equipment, and mobility.

Residential mobility can be assumed to have at least three important influences upon the frequency of family camping: (1) the move often places the family in an area where they are less familiar with the camping opportunities around them; (2) family moves are often made in the summer to minimize conflicts with school and work, which maximizes conflicts for the use of leisure time; and (3) recreational opportunities are not evenly distributed across the country.

During the study, 148 of the 565 panel members moved at least once, and 7 percent moved more than once (fig. 2). Of those that moved, 41 percent reported declining camping, as opposed to 30 percent of those campers who did not move during the 4-year period (table 6).

The decline in camping among those who moved during the

Figure 2.—Initial/final distribution of the New England camper panel.

Table 6.—*Percent of panel in three camping-trend groups by residential mobility classes*

Mobility	Camping trend		
	Increasing	Constant	Decreasing
	Pct.	*Pct.*	*Pct.*
Mobile (n=148)[1]	15±3.4[2]	44±4.6	41±4.5
Stable (n=417)	18±3.4	52±4.6	30±4.5

[1]Residentially mobile campers have moved at least once during the 4-year period.
[2]Refer to table 2 for explanation of standard error computation.

study is probably temporary, because camping can provide an element of stability for those families that are both residentially and socially mobile.

Many panel members offered explanations when their camping frequency was temporarily reduced. Of these, only 10 specifically mentioned moving or a change of jobs as having influenced their camping. By far the most frequently mentioned limiting factors were sickness, accidents, hospitalization, births, and deaths in the family (mentioned by 60 campers). Other common explanations for a reduction in camping were: dissatisfaction with camping experiences, loss of interest, or a change of interest — such as building a second home—(mentioned by 22 campers); children occupied during the summer, and children losing interest in camping (mentioned by 12 campers); and increased cost or reduced available income to spend on camping (mentioned by 9 campers).

Given equivalent resources of time and money, the opportunity to camp distills to a question of relative convenience. The more convenient camping is, the more apparent are its opportunities. Camping's increasing convenience during the period of this study (1964-1969) is reflected by an estimated doubling in the number of available campsites nationally, and recreational vehicle production that grew to 500,000 units in 1970 from about 60,000 in 1960.

The convenience of hitching up to a fully equipped recreational vehicle, as opposed to hours of packing and unpacking

tents and other bulky equipment, should produce more nights of camping for a family. Among panel members who were using tents 5 years ago, 35 percent reported declining participation rates, as opposed to 29 percent of those who were already using some type of recreational vehicle. However, the effect of recreational vehicle convenience on camping frequency is most apparent when those campers who made the transition from tents to vehicles (17 percent) are compared with those who only used tents (37 percent) or those who consistently used vehicles (41 percent) for the entire 4-year period (table 7). The average annual days camped by these three groups were:

	Year one	*Year two*	*Year three*	*Year four*
From tents to vehicles	23	26	25	28
Used tents every year	16	14	13	11
Used vehicles every year	27	25	24	24

Of course, panel members continued to purchase tents and trailers throughout the study; and 55 percent of all the recreational vehicles purchased were bought by campers who were already vehicle campers. Almost one-half of the campers who had declining participation in camping made at least one major purchase of equipment during the 4-year period. And contrary to our finding that the declining campers were also declining in their participation in other outdoor activities, we found that purchases of non-camping outdoor recreation equipment were numerous and increased slightly (table 8). This seems to suggest that the person whose total outdoor recreation participation is

Table 7.—*Percent of campers with increasing and decreasing camping trends, according to types of camping equipment in use*

Equipment used over 4 years:		Camping trend	
		Increasing	Decreasing
	No.	*Pct.*	*Pct.*
Tents only	207	8	45
Recreational vehicles only	233	18	30
Switched from tents to vehicles	95	33	15

Table 8.—*Number of campers making annual equipment purchases, by camping trend groups, and according to type of outdoor recreational equipment purchased*

Trend	Year one	Year two	Year three	Year four
	No.	*No.*	*No.*	*No.*
Increasing camping:				
Camping equipment only	23	20	21	17
Camping and other	12	13	14	12
Other equipment only	16	20	20	22
Constant camping level:				
Camping equipment only	49	46	27	30
Camping and other	47	29	22	27
Other equipment only	69	82	83	78
Decreasing camping:				
Camping equipment only	35	17	10	4
Camping and other	21	11	3	5
Other equipment only	60	60	68	68

declining nevertheless maintains a high level of outdoor interest and may subsequently increase his actual participation when he is able to.

The major items of recreational equipment purchased by the panel, and their frequency of purchase for the 4 years were:

Item	*Frequency*
Fishing and hunting equipment	498
Motor homes, pick-up campers, tent trailers, and trailers	282
Skis	280
Tents	226
Boats	163
Sleeping bags, lanterns, etc.	88
Outboard motors	79
Snow vehicles	12

By comparison, the panel also purchased 863 motor vehicles over the 4 years. And only 83 of the 565 panel members failed to buy at least one automobile during this period.

The purchase of a recreational vehicle and both the trend and volume of camping participation are highly correlated (.01 level). Among the 209 panel members purchasing at least one recreation vehicle, 29 percent reported increasing trends and 16 percent decreasing trends in their camping. Of the 356 panel-

ists who did not purchase a recreation vehicle, 10 percent increased and 42 percent decreased their participation. The average number of days camped for these two groups were:

Recreation vehicle	*Year one*	*Year two*	*Year three*	*Year four*
purchasers	25±1.1	26±1.2	27±1.4	29±1.6
Remainder of the panel	20± .7	18± .8	16± .8	14± .9

Several anticipated limitations did not appear. For example, no significant correlations were found between camping trend or camping volume and any of the following: family size, change in family size, income, and change in income (table 9).

Table 9.—*Percent of families with increasing or decreasing camping trends, according to several categories of family size and income*

Category and number		Camping trend	
		Increasing	Decreasing
	No.	*Pct.*	*Pct.*
Small families[1]	276	18	30
Large families[1]	279	17	35
Growing families	78	12	42
Constant families	410	18	30
Shrinking families	76	16	37
Average income[2]	319	19	30
High income[2]	241	15	35
Constant income[3]	204	17	32
Slow income gain[3]	199	17	32
Rapid income gain[3]	129	16	35

[1]Small families have 2 or less children; large have over 2.

[2]Average is $150 or less gross income per week in 1964-65; high is over $150 per week.

[3]Constant means less than a $1,000 net increase over the 4-year period; slow indicates a $1,000 to $2,000 net increase; and rapid means a periodic increase of more than $2,000.

Effects of Habit and Style on Participation

Earlier studies have reported the influence of various habit patterns on camping participation. A study of campers in New Hampshire *(1)* described a "repeat-visit cycle" in which the incidence of past visits to a campground results in longer visits

and more definite plans to return for a future visit. Another New Hampshire study *(2)* identified campers whose loyalty for specific campgrounds sharply reduces their annual volume of camping. Still another recent study *(3)* identified a "heavy-half" of the camping market, or that half of the active campers who camp more than the median number of days, and who are responsible for three-fourths or more of the total annual reported camping activity. These heavy campers consistently camped more and increased their annual volume of camping while the light half camped less and revealed a declining trend as well.

The New England camper panel provides an opportunity to study each of these habit patterns in detail and over time. We found a consistency among campers in either the light or heavy half of the market. One group comprising 27 percent of the camper panel consistently camped more than the median number of days, year after year. These campers accounted for 51 percent of all reported camping activity over the 4-year period. Another group comprising 26 percent of the panel was consistently in the light half of the panel and accounted for only 9 percent of total camping days. The remaining 47 percent shifted back and forth between the halves, camping more than the median in some years and less in others; and this group accounted for 40 percent of the total camping days.

Table 10.—*Average annual participation among campers who consistently camped more and less than the annual median number of camping days or whose participation was erratic*

Category	Year			
	One	Two	Three	Four
	Days	*Days*	*Days*	*Days*
Consistently heavy campers	36±1.4[1]	40±1.4	40±1.5	41±1.8
Consistently light campers	11± .3	7± .5	5± .4	5± .4
Erratic camping participation	20± .7	18± .7	17± .8	18± .8

[1]Refer to table 2 for explanation of standard error computation.

A camper's past volume of camping has a highly significant (.005 level) correlation with his camping trend (Appendix, table 13). Campers in the heavy-half of the panel tend to increase their levels of participation (table 10). Only 6 percent of these campers reported declining participation. Among consistently light campers, 57 percent had declining rates of participation.

There are no significant differences in residential mobility or age structure of these three groups; although consistently heavy campers tend to be slightly older than either of the other two groups.

These participation trends among heavy and light campers have the effect of further obscuring any life-cycle influence that may govern camping participation. That is, if a life-cycle influence was operating, we should expect to find light campers with increasing participation trends, and heavy campers with either constant or decreasing trends.

Although we have no strict measures of the panel members' preferences for commercially developed and publicly developed campgrounds, about one-half of the panel was recruited at each type of development. Past research indicates that some important differences exist in camper preferences, equipment, and participation patterns between visitors to these two types of campgrounds *(1, 2)*. Consequently, we compared the camping trends of panel members according to the type of campground — public or private — where the initial contact was made. The proportion of declining campers was found by chi-square tests to be significantly higher (5-percent level) at publicly developed campgrounds (table 11).

During the initial field interview, each camper having at least 1 year of camping experience was asked to characterize his camping style as either: (1) generally preferring to restrict camping visits to two or three carefully selected campgrounds (restrictive); or (2) generally preferring to explore new campgrounds on each trip (exploratory). Restrictive and exploratory campers were evenly represented at the public campgrounds. However, the restrictive style was more than twice as common at commercial campgrounds (table 11). This tendency toward

Table 11.—*Percent of panel members contacted at public and commercial campgrounds with increasing, constant, and decreasing camping trends, according to two different styles of camping participation*

Category	Camping trend		
	Increasing	Constant	Decreasing
	Pct.	*Pct.*	*Pct.*
Contacted at public campgrounds (n=280)	18±2.3[1]	44±2.9	38±2.9
Restrictive style of camping (n=116)	23±3.8	47±4.5	30±4.2
Exploratory style of camping (n=115)	12±3.0	43±4.5	45±4.5
Contacted at commercial campgrounds (n=285)	16±2.1	57±2.9	27±2.6
Restrictive style of camping (n=186)	17±2.7	56±3.5	28±3.2
Exploratory style of camping (n=81)	16±4.0	61±5.3	23±4.6

[1]Refer to table 2 for explanation of standard error computation.

limiting visits to carefully selected private campgrounds seems logical in view of the greater range in quality and services among commercial developments than among the public campground developments.

The significantly higher proportion of declining campers found at public campgrounds is heavily concentrated among those campers having an exploratory type of camping participation. The heavy decline in camping by this group may be a reflection of the increasingly crowded conditions at most public campgrounds and the inability to be assured of finding available space.

Another way of indexing a camper's style of camping is by examining his attitudes about the activity. During the initial interview, each camper was asked for his agreement or disagreement with several different definitions of camping. One of these definitions stressed the physical aspects of camping in the classical sense of a return to nature; while another definition depicted camping in a more contemporary role as a social experience. From these two definitions, four impressions of camping emerge: (1) camping is a social experience, not a physical one, 10 percent;

(2) camping is a physical experience, and not social, 27 percent; (3) camping is neither physical nor social, 28 percent; and (4) camping is both a social and physical experience, 34 percent. The trends for these four groups are:

	Percent declining campers	*Percent increasing campers*
Social (n=53)	21±5.5	19±5.3
Physical (n=142)	35±3.9	20±3.3
Neither (n=147)	37±3.9	12±2.6
Both (n=177)	29±3.3	19±2.9

Another way of indexing camper attitudes about camping requires that the camper express a preference for a camping vacation over several other attractive alternatives. During the initial interview, each camper was asked to rate two different styles of camping — remote wilderness and developed auto-access camping — against five other non-camping types of vacations. Out of the 565 panel members, only 97 selected wilderness camping as either their first or second choice for a vacation. During the 4-year period, these wilderness-oriented campers had significantly different camping trends from the rest of the panel. Forty-three percent had declining participation and only 8 percent increased their camping, as compared to 31 percent and 19 percent, respectively, in the remainder of the panel. The wilderness-oriented campers were also more likely to be tent campers (62 percent v. 52 percent and more likely to have been camping for at least 8 years (43 percent v. 31 percent) before joining the panel.

In summary, factors of habit and style of camping co-vary more with camping trends than do factors of life-cycle and opportunity. Commonly associated with a declining camping trend are factors of: (1) a low past volume of camping, (2) an exploratory style of camping combined with an apparent preference for non-commercial campgrounds, and (3) a traditional or wilderness orientation toward camping.

CONCLUSION

Our major conclusion, that per capita outdoor recreation participation of the camper panel declined, hinges on two unanswered questions. First, after only 4 years of study, have we detected real trends; and second, if the trends are real, can we account for the inadequate explanations provided by life-cycle effects, changing interests, opportunity limitations, and habit patterns? Both questions rate a qualified yes.

The need to convert annual participation figures to running averages is some indication of the difficulty in discerning clear trends in the data. In fact, this procedure forces a trend out of the data, and some such procedure would also be necessary in a longer study in order to iron out the peaks and dips of short-term changes in participation. However, this procedure forces an artificial trend out of the data only to the extent that the threshold limits chosen are reasonable. If the determinants of a trend are set at ± 10 percent, ± 20 percent, and ± 30 percent, the same ratio of two decreasing campers for each increasing camper is found. If the determinant of a trend is set at a change of ± 5 percent, constant participation is practically eliminated. With the threshold limits of ± 20 percent we chose for this study, one-half of the panel is classed as having "constant participation". Certainly, with limits set as liberally as this, we are measuring real trends. Of course, this says nothing about their reversibility.

The failure of the study to explain these trends must be attributed to a variety of causes. First, the small size of the final panel, particularly the size of the increasing participation subset, makes multi-variate analysis difficult. Human behavior is rarely explainable in terms of bi-variate relationships. Second, the validity of the indices chosen as representative of life-cycle, opportunity, and habit is generally untested. Other indices of these same effects might have proven to be much more significant covariates of the trends. Finally, a large portion of the trend behavior may be due to other unmeasured variables.

This later possibility deserves special attention. Unfortunately, panel members were never specifically asked to explain their changes in annual participation. This oversight effectively elimi-

nates any chance to consider the effects of changes in the camping experience itself, relative to trends in campground conditions and campground management.

We can consider that any given camper's trend in camping is a product of two broad classes of variables — individual and environmental. This study concentrated only on those individual constraints that make camping a reasonable alternative use of leisure time. But the basic attractiveness of camping is environmental, and people will make time available to camp if the camping environment is sufficiently attractive.

Because we lack a clear expression of the effect of environmental change, we are forced to return to the basic finding that twice as many campers had declining participation trends as had increasing trends, and to speculate about environmental causes. The relative high rate of decreasing participation among exploratory style campers contacted at public campgrounds seems consistent with the increasingly heavy use of these parks that has produced crowding and other forms of environmental deterioration. The direct exposure to these conditions as well as the indirect exposure through the media publicizing these conditions may be responsible for a part of the reduction in per-capita participation and may be causing a shift from public parks to commercial campgrounds.

Long-term panel studies of outdoor recreational behavior are expensive and difficult to maintain. This study has shown that the interest and cooperation of the camping public makes such studies feasible. More — and more penetrating — panel research can provide basic outdoor recreation planning information about the ways in which people make substitutions between different activities and events. At a minimum, this study seriously challenges the planner's common assumption that increasing per-capita participation is a prime cause of rising demands for outdoor recreation facilities and services.

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■

APPENDIX

Table 12.—*A comparison of selected characteristics of 864 campers initially contacted with 565 panel members who eventually submitted 4 full years of outdoor recreation participation data*

Item	Initial survey	Final panel
	Pct.	*Pct.*
Source of initial camper contacts		
Campground:		
1	12	13
2	12	13
3	12	12
4	12	11
Total public campgrounds	48	49
5	13	13
6	13	11
7	13	13
8	13	13
Total commercial campgrounds	52	51
Initially members of camping clubs	21	23
Initially beginning campers with less than 3 years experience:	25	24
Initially in agreement with a social definition of camping:	45	43
Initial age structure:		
Under 31	14	16
31 to 40	42	41
Over 40	44	43
Initial camping style:		
Restrictive	52	53
Exploratory	34	35
Undetermined	14	12
Initial weekly income distribution:		
$100 or less	21	20
About $150	38	36
$200 or more	41	43

Table 13.—*Correlation coefficients (r) for 10 measures of camping and annual outdoor recreation activity*[1]

	Trend	C-1	C-2	C-3	C-4	E-1	E-2	E-3	E-4
Trend	1.0	0.055	0.167	0.520	0.592	—0.030	0.047	0.153	0.132
C-1	—	1.000	.630	.566	.531	.242	.181	.130	.170
C-2	—	—	1.000	.706	.640	.167	.230	.160	.189
C-3	—	—	—	1.000	.770	.153	.201	.264	.224
C-4	—	—	—	—	1.000	.173	.200	.208	.318
E-1	—	—	—	—	—	1.000	.642	.592	.542
E-2	—	—	—	—	—	—	1.000	.686	.594
E-3	—	—	—	—	—	—	—	1.000	.599
E-4	—	—	—	—	—	—	—	—	1.000

[1]For computing correlations, camping trend was coded as 1, 2, or 3, for trends that were decreasing, constant, or increasing, respectively. Variables C-1 through C-4 are the actual days of camping spent in years 1 through 4. E-1 through E-4 are the actual number of outdoor recreation events (exclusive of camping) engaged in each year.

THE FOREST SERVICE of the U. S. Department of Agriculture is dedicated to the principle of multiple use management of the Nation's forest resources for sustained yields of wood, water, forage, wildlife, and recreation. Through forestry research, cooperation with the States and private forest owners, and management of the National Forests and National Grasslands, it strives — as directed by Congress — to provide increasingly greater service to a growing Nation.

Seasonal Recovery of **CHLOROTIC NEEDLES** *in Scotch Pine*

by Jerry K. Jones

JUL 23 1971

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NORTHEASTERN FOREST EXPERIMENT STATION, UPPER DARBY, PA.
FOREST SERVICE, U.S. DEPARTMENT OF AGRICULTURE
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The study reported in this paper was done by the author as part of his graduate studies, in cooperation with the Northeastern Forest Experiment Station's project 1502, timber-related crops research, under the direction of Dr. Arnold Krochmal, project leader. The project, with headquarters at Berea, Kentucky, provided materials, trees, and laboratory facilities for the study.

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Seasonal Recovery of CHLOROTIC NEEDLES in Scotch Pine

DISCOLORED NEEDLES AND CHRISTMAS TREES

SCOTCH PINE, which is planted widely for use as Christmas trees, has an unfortunate tendency to discolor during the winter months. The needles of many trees turn yellow just at the time when rich green foliage is wanted. This, of course, is of great concern to Christmas tree growers.

As part of a research project on Christmas trees being carried on by the USDA Forest Service's Northeastern Forest Experiment Station, the author made a cooperative study of how discolored needles recover their normal color in February and April. Though this does not solve the Christmas tree growers' problem, it does shed some light on the process involved in the discoloration.

The study confirmed that the seasonal yellowing of the needles is due primarily to the loss of chlorophyll and, conversely, that a sharp increase in chlorophyll concentration accompanies the return to summer green.

BACKGROUND

When a plant exhibits unusual coloration, a nutrient deficiency is usually suspected. If with Scotch pine (*Pinus sylvestris* L.), a mineral deficiency is responsible for the discoloration, why does the discoloration take place only during the dormant season, and to different degrees among different races at the same site?

Gerhold (*1959a*) studied nine foliar elements in green and chlorotic needles collected in August and February from six races of Scotch pine, but could establish no connection between pigments and elements to account for any appreciable amount of discoloration.

Later Gerhold (*1959b*) established that short photoperiods, intense sunlight, and low temperatures are required for the discoloration to occur. He could not attribute any effect to relative humidity.

White and Wright (*1966*) used growth chambers to study the reverse change—from yellow to summer green. They found that branches maintained at a daytime temperature of 17°C. or higher regained color in a few days. High temperatures in the absence of light did not result in a color change, and the rate of change was affected very little by night temperature.

The pattern of discoloration is genetically fixed and does not change as the tree grows older. Dengler (*1938*) and Münch (*1924*) had shown earlier that needle color characteristics are indeed inherited by second-generation progeny on a foreign site, although site factors do exert some influence on phenotypic needle color (*Gerhold 1959a*).

MATERIALS AND METHODS

Three races of Scotch pine were selected for study solely on the basis of needle color. Two of these races (Spanish and Austrian) were grown in an outdoor plantation; and the third race (French) was grown in an environmental control chamber. The chloroplast pigments and the foliar nitrogen concentrations were determined for all three races.

Trees Grown in Plantation

Trees of the Spanish and Austrian races were growing in the 5-year-old plantations maintained by the USDA Northeastern Forest Experiment Station on the Berea College Forest, at Berea, Kentucky. Elevation was about 950 feet.

Six trees of each race were marked, and needle samples were collected six times from each tree in the periods from mid-February to early March and from Mid-April to early May. Fifteen needles of the current year's foliage were picked from the lateral branches on the south side of each tree, and were placed in vials.

Ten needles were taken from each vial. Those from tree 1 and tree 2 were placed together, and those from tree 3 and tree 4 were placed together, and so on. The combined total of 20 needles were then wrapped loosely in cheesecloth and placed in a −5°C. freezer for analysis of chloroplast pigment later. Five needles from each of the same pairs of trees were cleaned and placed in uncapped vials, which were then placed in an oven and dried at 65°C. for 2 weeks.

Trees Grown in Environmental Chamber

Two-year-old seedlings of the French race of Scotch pine were potted in sandy loam soil, using clay pots. Four seedlings were placed in a Sherer environmental chamber.

The seedlings were first subjected to a spring-like environment for 2 weeks. The temperature was maintained at 21°C. during the day and 10°C. during the night. Day-length was set at 14 hours, with the incandescent lights burning from 6 a.m. till 8 p.m. and the fluorescent lights burning from 11 a.m. till 3 p.m. At the end of 2 weeks a needle collection was made and handled in the same manner mentioned earlier.

After the first collection, the temperature was set at 40°C. during the day and 1.67°C. at night. Day-length was set at 10 hours, with the incandescent lights burning from 7 a.m. till 5 p.m. and the fluorescent lights burning from 1 p.m. till 3 p.m. After 3 weeks, when discoloration seemed to be at its maximum, a second collection was made.

After the second collection was made, the temperature and

photo-period were adjusted to simulate Kentucky conditions in April. The temperature was maintained at 21°C. during the day and 10°C. at night. Day-length was set at 14 hours, with the incandescent lights burning from 6 a.m. till 8 p.m. and the fluorescent lights burning from 11 a.m. till 3 p.m. In about 10 days, after the needles had regained their color, a final collection was made.

Chloroplast Pigment Determinations

The method of extraction and separation followed closely that of Schertz (*1928*). The concentration of pigments in solution was determined from absorption measurements taken with a colorimeter. Chlorophyll a was determined from the absorption at 663 mμ. and chlorophyll b from the absorption at 645 mμ.

Five-ml. aliquots of the acetone solution were then air-dried and the pigment residues were resuspended in 5 ml. petroleum ether for total carotenoid determination. Flavanoids were washed out of the ether solution with 5 ml. of 1-percent sodium carbonate solution, and chlorophylls were removed with methanolic potassium hydroxide (Snell *1967*, vol. 3a, pp. 24-31).

The following formulas derived by Gerhold (*1959a*) and Arnon (*1949*) were used:

Chlorophyll-a, grams per liter = 0.0127 (663) — 0.00269 (645)
Chlorophyll-b, grams per liter = 0.0229 (645) — 0.00468 (663)
Total carotenoids, mols per liter = 451/132, 590

Nitrogen Determination

For the determination of nitrogen, the Kjeldahl method was employed as outlined by Kabat and Mayer (*1961*) and C. Yang (personal communication, 1970)

RESULTS AND DISCUSSION

Chloroplast Pigments

It had been assumed previously, and demonstrated by Gerhold (1959a), that a decrease in chlorophyll accompanied by an increase in carotenoids is primarily responsible for the winter discoloration observed in the needles of Scotch pine. The results obtained in my study show an inverse relationship. My study dealt

with the changes in discolored needles as they convert from yellow to green, whereas Gerhold investigated the changes from green to yellow.

The Spanish race, the only one of the three that kept a good winter color, had the highest average concentration of chlorophylls a and b during the February-March period (table 1). The French

Table 1.—*Average chloroplast pigment content of current year's needles in three geographic races of Scotch pine*

[In grams per liter]

Date	Race	Chlorophyll		Total carotenoids
		a	b	
16 Feb 1970	Spanish	0.0554	0.0197	0.0294
	Austrian	.0439	.0155	.0188
21 Feb 1970	Spanish	.0551	.0219	.0450
	Austrian	.0503	.0195	.0173
24 Feb 1970	Spanish	.0882	.0343	.0444
	Austrian	.0653	.0201	.0448
28 Feb 1970	Spanish	.0507	.0241	.0629
	Austrian	.0308	.0355	.0486
8 Mar 1970	Spanish	.0586	.0200	.0394
	Austrian	.0329	.0205	.0344
10 Mar 1970	Spanish	.0725	.0199	.0359
	Austrian	.0545	.0183	.0219
6 Apr 1970	Spanish	0.0653	0.0235	0.0332
	Austrian	.0787	.0278	.0215
11 Apr 1970	Spanish	.0665	.0213	.0301
	Austrian	.0654	.0288	.0577
15 Apr 1970	Spanish	.0630	.0298	.0415
	Austrian	.0689	.0203	.0321
18 Apr 1970	Spanish	.0727	.0266	.0288
	Austrian	.0736	.0348	.0277
26 Apr 1970	Spanish	.0688	.0300	.0371
	Austrian	.0720	.0254	.0181
3 May 1970	Spanish	.0840	.0381	.0297
	Austrian	.0957	.0447	.0217
April	French	0.1094	0.0469	0.0238
February	French	.0364	.02088	.0267
April	French	.1317	.0689	.0235

and Austrian races, which were noticeably discolored, both increased their chlorophyll-a concentrations by over 200 percent. They also increased chlorophyll b: the Austrian race by 81 percent and the French race by 177 percent as their needles regained their summer color.

These findings provide a basis for stating that a reduction in total chlorophyll content in the needles of Scotch pine is primarily responsible for the discoloration of the needles in many races of Scotch pine during the winter months. And conversely, the sharp increase in total chlorophyll is responsible for the change from winter yellow to summer green.

Gerhold (*1959a*) found that the changes in carotenoid concentrations did not parallel changes in needle color, but did increase at about the same rate from August to February in races that discolor and those that remain green. He concluded that the carotenoids contribute to needle color, but that the primary cause of discoloration is the unmasking of the carotenoids by a sharp reduction in chlorophyll.

The Austrian race had an average of 55 percent less carotenoid concentration than the Spanish race in the February-March period, and an average of 31 percent less in the April-May period. The French race had an average of 42 percent less than the Spanish race during the February-March period and an average of 38 percent less during the April-May period. I found the average carotenoid concentrations in February-March were higher in the race that did not discolor than in the two races that did discolor.

This confirmed the basic assumption that a reduction in chlorophyll concentration rather than an increase in carotenoids is the major cause of discoloration.

Foliar Nitrogen

The fluctuation of chlorophyll content having been directly linked with the changes in needle color in Scotch pine gives additional assurance for reasoning further that if any nutrient element is involved in discoloration, it must bear a relationship to the chloroplast pigments. In this study, foliar nitrogen, which is essential for chlorophyll synthesis, was chosen as the element to be studied.

If a deficiency in nitrogen were responsible or partly responsible for the seasonal discoloration, then one would expect the nitrogen concentration to be lower in February in those races that discolor than in those that remain green. The results obtained in my study did not substantiate this assumption. Rather, the race that discolored the most (Austrian) had a 21-percent higher foliar nitrogen concentration in the February-March period than did the Spanish race (table 2), and maintained a 22-percent higher

Table 2.—*Average nitrogen content of current year's needles in three geographic races of Scotch pine*

Date	Race	Percent dry weight of nitrogen
16 Feb 1970	Spanish	0.73
	Austrian	1.04
21 Feb 1970	Spanish	1.19
	Austrian	1.27
24 Feb 1970	Spanish	.90
	Austrian	1.22
28 Feb 1970	Spanish	.85
	Austrian	1.27
8 Mar 1970	Spanish	.86
	Austrian	.99
15 Mar 1970	Spanish	.95
	Austrian	1.30
6 Apr 1970	Spanish	1.00
	Austrian	1.11
11 Apr 1970	Spanish	.94
	Austrian	1.03
15 Apr 1970	Spanish	.79
18 Apr 1970	Spanish	.69
	Austrian	.84
26 Apr 1970	Spanish	.77
	Austrian	.94
3 May 1970	Spanish	.75
	Austrian	.94
April	French	0.81
February	French	.92
April	French	.83

concentration when both races were green during the April-May period.

The French race, which did not discolor as noticeably as the Austrian race because a temperature below 1.67°C. could not be maintained in the environmental chamber, had a 3-percent higher foliar nitrogen concentration than the Spanish race during the April-May period.

In conclusion, no substantial evidence was found to account for any appreciable amount of discoloration due to a nitrogen deficiency. The ranges of nitrogen in the needles can be regarded as falling within the normal variability in Scotch pine.

SUMMARY AND CONCLUSIONS

Chloroplast pigments and nitrogen in the needles of three geographic races of Scotch pine were analyzed and related to seasonal discoloration. No attempt was made to determine why the chloroplast pigments fluctuate from one season to the next; rather the scope of this study was limited to determining foliar concentrations during February and March and comparing them with those of April and May. Chlorophylls a and b and total carotenoids were determined by spectrophotometry, and nitrogen was determined chemically.

Discoloration is caused primarily by the loss of chlorophyll, accompanied by an increase in carotenoid concentration. The needles regain their color when the process is reversed in the spring. In February, total chlorophyll was higher in the Spanish race than in the Austrian and French races, but in April the opposite was true. Carotenoids were higher in February than in April in all three races. No substantial evidence was found to account for any appreciable amount of discoloration due to a nitrogen deficiency.

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BY RUSSELL S. WALTERS

WHITE PINE PROVENANCES FOR Christmas Trees IN EASTERN KENTUCKY & OHIO

JUL 23 1971

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NORTHEASTERN FOREST EXPERIMENT STATION, UPPER DARBY, PA.
FOREST SERVICE, U.S. DEPARTMENT OF AGRICULTURE
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WHAT SEED SOURCE?

THOUGH EASTERN WHITE PINE is one of the species favored for use as a Christmas tree, little is know about geographic variation within the species, especially in those qualities that are important for Christmas trees—color, form, needle length, needle retention, and growth rate.

The question for a Christmas tree grower in eastern Kentucky and southeastern Ohio is, what seed source will produce the best tree?

In a study of trees grown from seed obtained from 16 regions throughout the natural range of white pine (*Pinus strobus* L.), the best Christmas tree qualities were found in trees grown from seed that came from the Appalachian Mountain regions and from lower Michigan.

BACKGROUND

Eastern white pine has many desirable characteristics for use as a Christmas tree (fig. 1). It is fragrant, has soft blue-green foliage, holds its needles well, and responds well to shearing. It is one of the 10 species used most for Christmas trees (*Souder 1966*).

For such a specialized use of a tree species, seed source (provenance) is important. Trees grown from seed that comes from

Figure 1. — An 8-year-old plantation-grown eastern white pine that has desirable Christmas tree qualities.

one part of the species' natural range may be different from trees grown from seed that comes from another part of the natural range.

In 1955 the Northeastern Forest Experiment Station began a cooperative study of eastern white pine provenances. Seed was collected from 16 areas (10 average trees at each) throughout the natural range of white pine—from Minnesota, Ontario, Quebec, and Nova Scotia south to Tennessee, North Carolina, and Georgia (fig. 2 and table 1).

From this seed, seedlings were grown at the Ralph Edwards State Forest Tree Nursery at Morganton, North Carolina, and then were outplanted as 2-year-old stock at a number of places to see how seedlings grown from seeds of each source would behave in these various other places.

Though these plantings were not designed with the idea of growing Christmas trees, the provenance plantings provided an opportunity for studying the trees from different seed sources to determine, at each planting site, which seed sources produced trees with the most desirable Christmas tree qualities.

Two plantations were selected for study, one in Laurel County, Kentucky, and one in Athens County, Ohio. The idea was that the seed sources in these two plantations that produced trees with the best Christmas tree qualities would be the best sources of seed

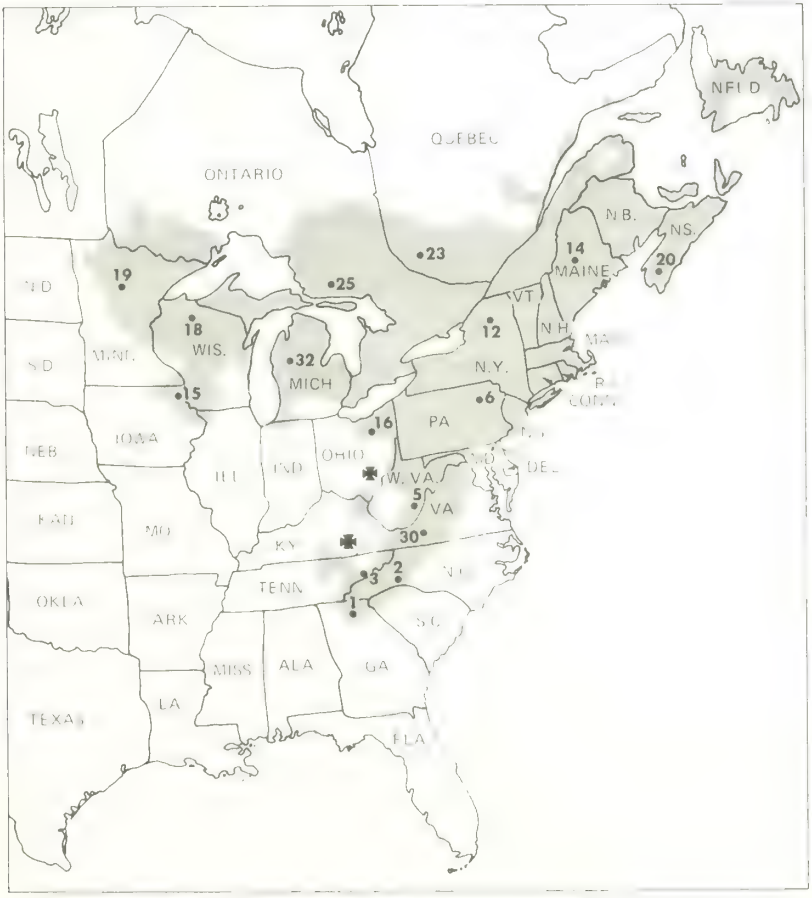


Figure 2.—The range of eastern white pine. The numbers mark the seed sources. The X's mark the experimental plantings in Laurel County, Kentucky, and Athens County, Ohio.

Table 1.—*The eastern white pine provenances studied*

Seed source	Latitude N.	Longitude W.	Elevation, feet
1. Georgia, Union County	34° 46′	84° 03′	2,450
2. North Carolina, Transylvania County	35° 14′	82° 38′	2,120
3. Tennessee, Greene County	36° 00′	82° 48′	2,250
5. West Virginia, Greenbrier County	38° 02′	80° 30′	2,600
6. Pennsylvania, Monroe County	41° 05′	75° 25′	1,800
12. New York, Franklin County	44° 25′	74° 15′	1,600
14. Maine, Penobscot County	44° 51′	68° 38′	150
15. Iowa, Allamakee County	43° 28′	91° 30′	1,000
16. Ohio, Ashland County	40° 45′	82° 15′	1,000
18. Wisconsin, Forest County	45° 51′	88° 54′	1,500
19. Minnesota, Cass County	47° 23′	94° 25′	1,300
20. Nova Scotia, Lunenburg County	44° 25′	64° 35′	150
23. Quebec, Pontiac County	47° 30′	77° —	1,000
25. Ontario, Algoma District	46° 10′	82° 37′	650
30. Virginia, Pulaski County	37° 05′	80° 50′	2,400
32. Michigan, Newaygo County	43° 30′	85° 40′	600

for growing Christmas trees in the general region between and about these two plantations.

STUDY METHODS

In both plantations, the author collected data on foliage color, needle length, needle retention, and height growth. The data were collected in midwinter because it is at this time that needle characteristics are most important for Christmas trees.

For each seed source in both plantations, four trees were sampled. No data were collected from chlorotic or unthrifty trees in either planting. Very few such trees were observed, and no definite trend of this sort could be detected among seed sources.

For measuring needle length, three or four fascicles were collected from the midpoint of the leader of each sample tree. Length was measured to the nearest millimeter .

Needle length is important for Christmas trees because it affects crown density. A tree with a dense crown and long needles usually sells faster than a tree with a thinner crown and shorter needles.

For evaluating needle color, sample needle fascicles from each

tree in the plot were stapled to a white card; and a team of two observers rater the color for each seed source.

Color was ranked from dark blue-green—considered the most desirable—to lighter yellowish green.

A two-man panel was considered effective for making color determinations (*Windle and Dingman 1960*). In fact, for many such value judgments a one-man test is considered adequate; for example, for coffee, tea, and wine.

The two people on our panel worked independently, and statistical analysis of their evaluations showed a high correlation. Color perception of both panel members was tested with the Ishihara Standard Color Blindness Test, and both showed normal color perception.

Needle retention was determined by examination of sample trees from each source. Needle retention is important for Christmas trees because it affects crown density. Most white pines in winter have needles both from the current year and one past year. A tree that has needles only from the current year's growth always appears thin, no matter how well shaped or well branched it is. Neither in Kentucky nor Ohio was evidence of partial needle drop observed on those trees retaining 2-year needles.

Tree heights were not measured, because the study plantings had already grown beyond the usual Christmas tree size. However, we had data from measurements made of these plantings at 5 years of age (*Funk 1964*). At 5 years a plantation has usually established its growth pattern; and white pines planted for Christmas trees are expected to be 3 to 3½ feet tall at 5 years.

Of course height growth is important for a Chrismas tree planting. Very slow growth causes a long rotation. Very fast growth is not necessary, because excess growth is removed by shearing anyway.

RESULTS

From the criteria studied, the trees grown from seed from the 16 seed sources were ranked to indicate which seed sources can be expected to produce the best Christmas trees in the eastern Kentucky—southeastern Ohio region.

Foliage Color

The study showed that foliage color can be used for selecting eastern white pine seed sources for use in growing Christmas trees.

Both observers detected green color differences among sources, and their rankings of these sources were associated with color. Further, both observers tended to assign each source to about the same color ranking within each replication. This was determined by correlation analyses computed between observers for their color rankings within each of the 12 Kentucky replications. All but two of the resulting correlation coefficients (r) were significant (table 2).

The 12 groups of color rankings made by each observer for the Kentucky planting were subjected to the Friedman two-way analysis of variance by ranks (Siegel 1956). This indicated a strong association between color ranking and seed source. The probability for each observer was less than 0.1 percent that his consistent ranking of seed sources was due to chance rather than color.

The color-ranking data for the Ohio planting were analyzed in the same way. The probability that the observed ranking arrangement by each observer was due to chance rather than color association was almost 10 percent.

This indicated that each observer found greater color variation among replications of a given source in the Ohio planting than in the Kentucky planting. On the other hand, both observers agreed well in their color ranking of sources within the replications. This

Table 2.—Correlation coefficients between color ranking by two observers in each of 12 replications in Kentucky

Replication	Correlation coefficient [1]	Replication	Correlation coefficient [1]
I	0.39	VII	0.81**
II	.52*	VIII	.81**
III	.72**	IX	.86**
IV	.52*	X	.24
V	.87**	XI	.64**
VI	.54*	XII	.86**

[1] * = Significant 5-percent level.
** = Significant 1-percent level.

Table 3.—*Average color ranking of 16 eastern white pine provenances by two observers*

Color [1] rank	Kentucky		Ohio	
	Observer J	Observer R	Observer J	Observer R
16	Tennessee	W. Virginia	Ohio	Nova Scotia
15	W. Virginia	Michigan	Nova Scotia	W. Virginia
14	Michigan	N. Carolina	W. Virginia	N. Carolina
13	N. Carolina	[Georgia	N. Carolina	Minnesota
12	Pennsylvania	Tennessee [2]]	Georgia	Ontario
11	Georgia	Virginia	Ontario	Pennsylvania
10	Wisconsin	Pennsylvania	Pennsylvania	Quebec
9	Virginia	Wisconsin	Wisconsin	Maine
8	Ontario	Nova Scotia	[Michigan	[Iowa [2]
7	Ohio	New York	New York [2]]	Michigan]
6	Nova Scotia	Ohio	Virginia	Wisconsin
5	Iowa	Iowa	Iowa	[New York [2]
4	New York	Ontario	Minnesota	Ohio]
3	Maine	Quebec	Tennessee	Tennessee
2	Quebec	Maine	Quebec	Georgia
1	Minnesota	Minnesota	Maine	Virginia

[1] In descending order, from greenest (16) to least green (1).
[2] Brackets indicate tied scores.

was shown by correlation analyses between observers for their rankings in each replication. The correlation coefficients were 0.32, 0.58*, 0.58*, and 0.52*, for each replication respectively. The latter three were significant at the 5-percent level.

The color rankings of the 16 eastern white pine provenances in the Kentucky and Ohio plantings are summarized in table 3. The Kentucky averages are based on observations from 12 replications by each observer and the Ohio averages from 4 by each observer.

To determine if there was a color association among observers and locations, these average color rankings were also subjected to the Friedman analysis. The association indicated by this analysis is good; the probability of this arrangement by chance is less than 2 percent. This means that there are differences in color among the provenances and that these can be detected. The same sources were consistently ranked as more green and others as less green by both observers in both plantations.

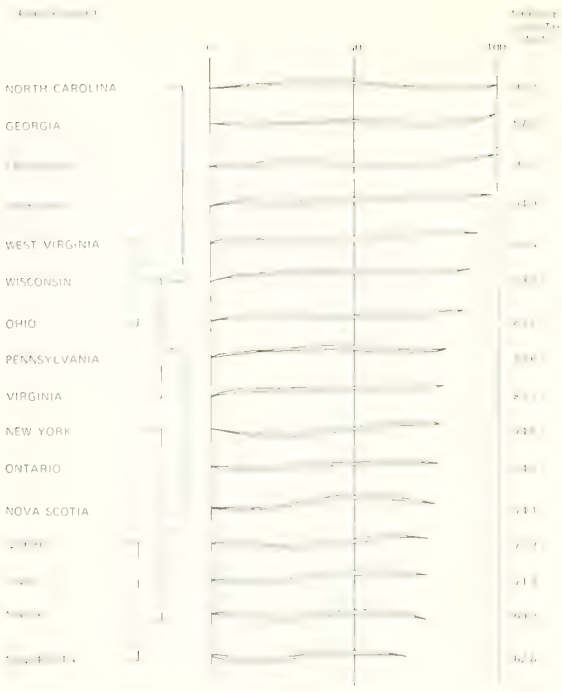


Figure 3.—Average white pine needle length in the Kentucky planting, by provenances. Brackets mark provenances not significantly different in needle length.

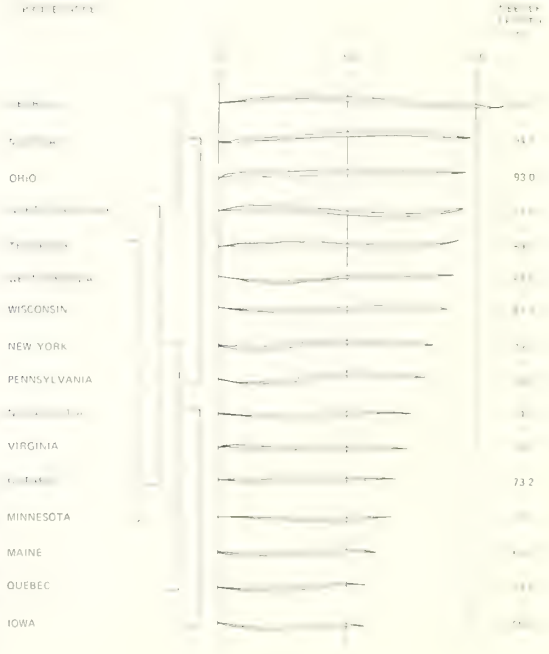


Figure 4.—Average white pine needle length in the Ohio planting, by provenances. Brackets mark provenances not significantly different in needle length.

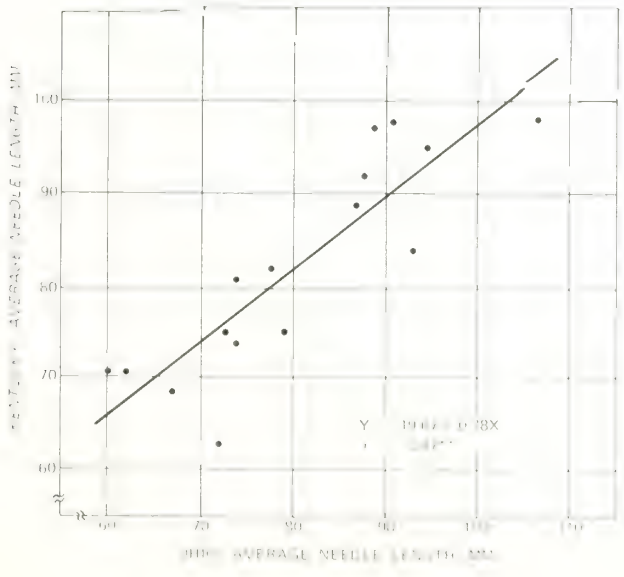
Needle Length

Considerable variability in needle length was found among seed sources (fig. 3 and fig. 4). In the Ohio planting, the longest needles measured were from Georgia trees, and the shortest were from Iowa trees. The Georgia needles were 107.0 mm. long and were 79 percent longer than the Iowa needles, which were 59.8 mm. long. In the Kentucky planting, the longest needles were those of the North Carolina trees, 98.2 mm., and the shortest were those from Minnesota trees, 62.8 mm. The North Carolina needles were 56 percent longer than the Minnesota needles.

Analysis of variance showed that the differences among provenances were highly significant (1-percent level) in both the Ohio and Kentucky plantings.

The correlation between average needle lengths for the trees planted in Kentucky and those planted in Ohio was highly significant (fig. 5). This indicates small within-source differences between the two planting sites. The largest difference found was only 11.3 mm., within the Iowa source. Where differences were observed, the trees in Kentucky generally had the longer needles.

Figure 5.—The average needle lengths of 16 eastern white pine provenances planted in Kentucky and Ohio.



Needle Retention

During the winter, foliage of most eastern white pines have needles from 2 years, those of the current year plus those of the previous year. Some trees retain only the needles of the current year. No white pines were found with needles of more than two growing seasons (table 4).

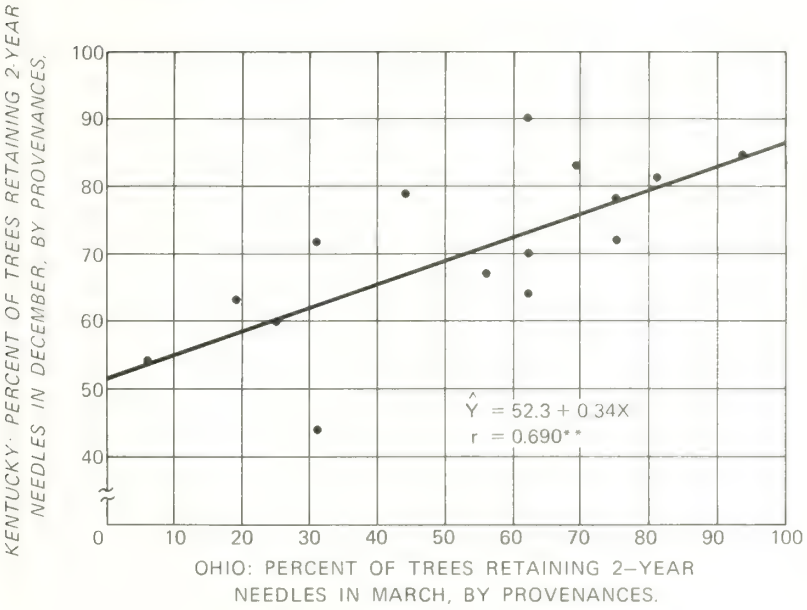
Analysis of variance indicated highly significant differences in average number of years of needle retention among provenances. This was observed in both the Kentucky and Ohio plantings. Furthermore, a correlation analysis (fig. 6) calculated between the percentage of trees retaining 2-year needles was significant at the 1-percent level. Therefore not only were differences found in needle-retention ability among provenances in both the Kentucky and Ohio plantings, but general agreement was found between the two planting sites. Provenances having a large percentage of trees with 2-year needles in one planting also had a large percentage in the other planting.

No one source in either planting was completely uniform. In Kentucky, the highest percentage of trees with 2-year needles was

Table 4.—*Percentage by provenance of eastern white pine trees retaining two seasons' needles*

Kentucky		Ohio	
Provenance	Percent	Provenance	Percent
Pennsylvania	90	Ohio	94
Ohio	85	Georgia	81
Tennessee	83	Michigan	75
Georgia	81	W. Virginia	75
Nova Scotia	79	Tennessee	69
Michigan	78	Minnesota	62
New York	72	N. Carolina	62
W. Virginia	72	Pennsylvania	62
N. Carolina	70	Wisconsin	62
Ontario	67	Ontario	56
Wisconsin	64	Nova Scotia	44
Minnesota	64	Maine	31
Quebec	63	New York	31
Virginia	60	Virginia	25
Iowa	54	Quebec	19
Maine	44	Iowa	6

Figure 6.—The percentage of trees retaining 2-year needles, for each of the 16 eastern white pine provenances planted in Kentucky and Ohio.



90 percent, and the lowest was 44 percent. In Ohio, the range was even greater, from 94 to 6 percent. Because of this variation and because of the agreement among sources in needle retention, seed for Christmas trees should be collected only from those eastern white pine provenances that have good needle retention.

Height Growth

The tree-height measurements taken by Funk (*1964*) were used for comparing provenances (fig. 7 and fig. 8). He had measured 15 of the 16 provenances 5 years after planting, but omitted the Michigan trees in his report because they had been planted a year later. For the Michigan trees in the Kentucky plantation we used his measurements at 4 years and projected them to 5 years. But 5-year height measurements had been made for the Michigan source in the Ohio planting, and we used these data.

The trees in the Kentucky planting have grown faster than those in the Ohio planting. However, the order of provenances is simi-

lar in both plantations. The white pines from North Carolina, Tennessee, and Georgia were the three tallest in Kentucky. These same three were also the tallest in Ohio, although in a diffrent order.

Hartley's multiple-range test showed that in each plantation the height differences among trees of the top three sources were not significant (*Snedecor 1956*). These three tallest sources where significantly taller in each plantation than the trees from Quebec, New York, Iowa, Maine, and Minnesota.

In the Kentucky planting, nine of the provenances were taller than the arbitrary standard of 3.5 feet, but in the Ohio planting only the Georgia trees surpassed this standard. However, average height of the Tennessee trees was almost as great as the standard and was not significantly different from the Georgia trees. Furthermore, the North Carolina, Pennsylvania, and Ohio trees averaged approximately 3 feet tall; and—although shorter than the Tennessee average—this height difference was not significant and therefore was considered satisfactory. These five tallest provenances in the Ohio planting were also among the six tallest in Kentucky, if the Michigan trees are included.

Figure 7.—Average heights of eastern white pine provenances in the Kentucky planting, after 5 years. Brackets mark provenances not significantly different in height growth.

Figure 8.—Average heights of eastern white pine provenances in the Ohio planting, after 5 years. Brackets mark provenances not significantly different in height growth.

Seed Source Rank

A weighted rank for each seed source was determined by combining the rankings for all the criteria studied (tables 5 and 6). The general rankings were as follows, from best to poorest:

Rank	*Kentucky planting*	*Ohio planting*
16	Tennessee	Georgia
15	Michigan	Ohio
14	North Carolina	North Carolina
13	Georgia	Michigan
12	Pennsylvania	West Virginia
11	West Virginia	Pennsylvania
10	Ohio	Tennessee
9	Wisconsin	Wisconsin
8	Nova Scotia	Nova Scotia
7	Virginia	Ontario
6	New York	Minnesota
5	Ontario	New York
4	Quebec	Virginia
3	Iowa	Maine
2	Minnesota	Quebec
1	Maine	Iowa

Table 5.—*Weighted ranking by tree characteristics of 16 eastern white pine provenances planted in Laurel County, Kentucky*

Seed source	Average color rank	Needle length	Needle retention	Height at 5 years	Weighted [1] rank
Tennessee	14	14	14	15	57
Michigan	15	13	11	14	53
North Carolina	13	16	8	16	53
Georgia	11	15	13	13	52
Pennsylvania	12	9	16	12	49
West Virginia	16	12	9	10	47
Ohio	7	10	15	11	43
Wisconsin	10	11	6	8	35
Nova Scotia	8	5	12	7	32
Virginia	9	8	3	9	29
New York	4	7	10	4	25
Ontario	6	6	7	6	25
Quebec	3	4	4	5	16
Iowa	5	3	2	3	13
Minnesota	1	1	5	1	8
Maine	2	2	1	2	7

[1] Sum of numerical rankings for all characteristics.

Table 6.—*Weighted ranking by tree characteristics of 16 eastern white pine provenances planted in Athens County, Ohio*

Seed source	Average color rank	Needle length	Needle retention	Height at 5 years	Weighted [1] rank
Georgia	10	16	15	16	57
Ohio	12	14	16	12	54
North Carolina	14	13	8	14	49
Michigan	8.5	15	14	10	47.5
West Virginia	15	11	13	6	45
Pennsylvania	11	8	11	13	43
Tennessee	2	12	12	15	41
Wisconsin	7	10	9	11	37
Nova Scotia	16	7	6	7	36
Ontario	13	5	7	8	33
Minnesota	8.5	4	10	4	26.5
New York	6	9	5	5	25
Virginia	1	6	3	9	19
Maine	3	3	4	2	12
Quebec	4	2	2	3	11
Iowa	5	1	1	1	8

[1] Sum of numerical rankings for all characteristics.

The average color rankings were developed as averages of the rankings of both observers. The rankings of the individual characteristics were consistent and highly significant. In addition, there was a highly significant correlation between the Kentucky and Ohio rankings.

CONCLUSION

The results from this study indicate that, of the provenances investigated, the white pine seed sources from the southern Appalachian mountains and lower Michigan offer the greatest Christmas tree potential for eastern Kentucky. The Tennessee source tops the list, followed by Michigan, North Carolina, and Georgia.

Three of these four sources are also at the top of the rankings for southeastern Ohio. The Georgia trees rank highest in the Ohio planting, followed by those of Ohio, North Carolina, and Michigan. However, the trees from Michigan were too slow growing after 5 years to be satisfactory for Christmas tree use.

The Tennessee trees ranked high in Kentucky but much lower in Ohio because of very low color rankings by both observers. The results suggest that the Tennessee source loses some of its Christmas tree potential when it is moved northward away from its place of origin, and the Ohio source seems to gain as it is moved closer to its place of origin. In contrast, the Michigan trees ranked higher in the most southerly plantation.

The data indicate that white pine seed to be grown for Christmas trees in eastern Kentucky should come from North Carolina or Georgia. Tennessee and lower Michigan seed sources could also be considered for use in southern Kentucky. Seed of the same sources—except Tennessee—appear to be suitable for southeastern Ohio planting sites. So do seed from the Ohio source.

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THE FOREST SERVICE of the U. S. Department of Agriculture is dedicated to the principle of multiple use management of the Nation's forest resources for sustained yields of wood, water, forage, wildlife, and recreation. Through forestry research, cooperation with the States and private forest owners, and management of the National Forests and National Grasslands, it strives — as directed by Congress — to provide increasingly greater service to a growing Nation.

BY JAMES S. JORDAN

YIELD
FROM AN INTENSIVELY HUNTED POPULATION OF
EASTERN FOX SQUIRRELS

U.S.D.A. FOREST SERVICE RESEARCH PAPER NE-186
1971

NORTHEASTERN FOREST EXPERIMENT STATION, UPPER DARBY, PA.
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The study reported here was made when the author was a research biologist in the Illinois Natural History Survey, Urbana, Illinois.

MANUSCRIPT RECEIVED FOR PUBLICATION 3 JULY 1969.

RATES at which Eastern fox squirrels *(Sciurus niger)* are exploited in areas open to public hunting may be useful guides for designing fall hunting seasons that are biologically defensible. However, there is a question whether the harvest of fox squirrels by public hunting will even occasionally be great enough to challenge the limit allowed by the best designed biologically sound hunting season. There seems to be a population level of squirrels—as yet undefined—that strongly resists further exploitation of its members by hunting, thereby preventing over-exploitation.

For example, at the Rose Lake Wildlife Research Station in Michigan, about 91 percent of the total harvest of 203 fox squirrels in 1966 occurred in the first 19 days of a 41-day open season *(Queal and Fouch 1967)*. Only 19 squirrels were taken in the last 22 days of the hunting season. Yet the estimated rate of exploitation of squirrels in 102 acres of woodlot within the general area open to hunting was only 59 percent.

In central Illinois, a 2-month hunting season in the 1950's did not seem to result in overexploitation of fox squirrels. It was thought that further interest in hunting rapidly declined after the first few weeks of the season, when hunting effort produced a low rate of return. If this was the case, then overexploitation might happen only if a hunting effort were applied throughout the season, regardless of a low rate of return from hunting.

In 1954, intensive hunting of fox squirrels was carried out in a 68-acre oak-hickory woods located near Havana in west-central Illinois. The objective was to maximize exploitation of the fox squirrel population by applying a high level of hunting pressure over the 61-day open season (1 September to 31 October) and to evaluate its effect on the size of the residual population. This report concerns that part of the study concerned with hunter success, the sex and age composition of bagged squirrels, and the size of the after-hunting-season population.

Study Area and Methods

The privately owned 68-acre study area was bounded on three sides by fields and a fenced pasture, and on the fourth and shortest side by a public road. Opposite this road was another oak-hickory woods and a young pine plantation. More than one-third of the study area was occupied by an old-growth timber stand; the balance of the area was well stocked with a mixture of pole- and sawtimber-size trees. The woods were posted against trespass during the study and were identified as a research study area. The population of fox squirrels had been under study for 8 months immediately preceding the hunting season.

Hunting was done by research personnel of the Illinois Natural History Survey. Hunting was generally limited to the daily periods of greatest squirrel activity—the early morning hours and late afternoon. Only the actual time spent hunting was recorded. The State game laws were observed. However, for the purpose of this study, the daily bag limit of 5 squirrels was applied to each hunting trip rather than to an individual hunter. Thus a hunter who made two trips on the same day was allowed the daily bag limit for each trip.

The sex, age, weight, and location of kill in the woods were recorded for each squirrel. Female squirrels were examined for evidence of lactation.

Live-trapping operations were conducted in August, October, and November. Trapped squirrels were ear-tagged and toe-clipped for identification and were released at the site of capture.

Results

HUNTING SUCCESS

Squirrels were hunted on 37 days of the 61-day season. Two hunters with an intimate knowledge of the study area did 91 percent of the hunting. In 60 hunting trips, 138 squirrels were bagged (table 1). An additional squirrel was killed but lodged in view at the top of a snag. Two other squirrels fell to the ground after being shot but were not found. An average of 2.3 squirrels were bagged per hunting trip. The time required to bag a squirrel averaged about 1 hour. Recorded kill averaged 2.0 squirrels per acre. A frequency distribution of the 60 hunting trips, by the number of squirrels bagged, is shown in table 2.

Hunting success was higher in the first half of September than in the second half, and lowest in October (table 1). However,

Table 1.—*Fox squirrels bagged and hours hunted, by 3-day periods, in a 68-acre oak-hickory woods near Havana, Illinois, 1 September through 31 October, 1954*

Period	Hunting trips	Squirrels bagged	Hours hunted	Kill per hour	Hunting conditions
	No.	*No.*	*Hours*	*No.*	
September:					
1-3	7	27	21.50	1.26	Excellent
4-6	4	9	8.25	1.09	Excellent
7-9	10	37	30.50	1.21	Excellent
10-12	8	19	16.75	1.13	Excellent
Subtotal	29	92	77.00	1.19	—
13, 16, 17	5	9	10.25	0.88	Poor to excellent
19-21	3	5	6.75	.74	Poor
22-24	5	7	9.25	.76	Poor
27-30	4	7	9.00	.78	Poor to excellent
Subtotal	17	28	35.25	0.79	—
October:					
4, 6, 7	3	3	5.75	0.52	Poor to excellent
8, 13, 15	3	2	5.50	.36	Poor
17-19	5	9	11.50	.78	Excellent to poor
24, 25, 31	3	4	6.25	.64	Excellent to poor
Subtotal	14	18	29.00	0.62	—
Totals	60	138	141.25	0.98	—

Table 2.—*Frequency distribution of hunting trips by the number of fox squirrels bagged in a 68-acre oak-hickory woods near Havana, Illinois, 1 September through 31 October, 1954*

Squirrels bagged	Hunting trips
No.	*No.*
0	8
1	17
2	9
3	10
4	7
5	9

the availability of squirrels to the gun appeared to be confounded with hunting conditions. The woods were quiet during the morning and afternoon hunting periods in the first half of September. But between 15 September and 5 October, with the exception of 2 or 3 days, the leaf litter was dry; and hunter movement through the woods was noisy. Many of the days from 6 October to the end of the month were windy; thus it was difficult to locate squirrels, and the woods were again noisy—so much so on a number of days that planned hunting trips were cancelled. One bag limit of 5 squirrels was taken in a total of 29 hunting trips from 16 September through 31 October.

SEX, AGE, AND WEIGHT OF BAGGED SQUIRRELS

There were more females than males among both adult and juvenile squirrels in the total bag. Of 38 adults bagged, 20 were females; among 100 juveniles bagged, 56 were females. Juveniles (spring- and summer-born, 1954) constituted 72.5 percent of the bagged squirrels. Of the total of 100 juveniles, 13 were from summer litters. There were 5.0 juveniles per adult female in the bag.

Adult females may have been slightly more vulnerable to the gun than were adult males or juvenile squirrels. All of the adult females bagged were taken by 20 September, whereas 67 percent of the adult males and 72 percent of the juvenile squirrels had been taken by the same date. Of the 20 adult females bagged, 17

(85 percent) were lactating, indicating that they had produced summer litters.

The smallest squirrel bagged (0.26 pound) was taken in good condition on 8 September. A second squirrel of about this size was seen at the same time. These squirrels may have been forced out of the nest after the loss of the female to hunting. Three lactating females were bagged before 8 September, within 300 feet of the above kill. The next smallest squirrels (0.44 and 0.45 pound) were bagged on 3 September.

The average weight of 13 summer-born squirrels was 0.68 pound. The average weights of 20 adult females, 18 adult males, and 86 juveniles (excluding summer-born individuals) were, respectively, 1.67, 1.70, and 1.38 pounds.

POPULATIONS

Live-trapping operations were carried out on 13 days between 5 and 29 October and on 5 days between 4 and 12 November. Eighty-three fox squirrels were captured—76 in October and 7 in November. Of those captured in October, 3 were bagged and 5 were found dead in the traps. Thus 68 marked squirrels were available for retrapping in November. Seventeen of these were actually retrapped, in addition to the 7 squirrels first captured in November. The estimated November population of squirrels in the study area, calculated by the Lincoln Index method, was 96 $\pm$ 25 (CL 0.95).

By adding together the 139 squirrels harvested during the hunting season, the 5 squirrels that were found dead in the traps, and the estimated November population of 96 squirrels, the total population on 1 September was estimated to be 240 squirrels. This was an average population density in the study area of 3.5 squirrels per acre. The rate of exploitation of the population through hunting was therefore 57.9 percent.

Another estimate of the September population was calculated by the Lincoln Index method. Forty-one individual squirrels were captured in the period 4 to 26 August. Twenty-one of these marked animals were among the total of 120 squirrels bagged 1 to 30 September. Thus, the estimated September population was 234 $\pm$ 93 (CL 0.95). This was very close to the previous esti-

mate of 240 squirrels, but the latter estimate was apparently more precise. Also, the validity of the estimate of 240 squirrels was strengthened by its similarity to an independent estimate that was free of the bias of a census derived from capture-recapture data.

Other methods of estimating the November population were investigated. The Schnabel (Krumholtz) procedure *(Davis 1963)* yielded an estimate of 130 squirrels, though the experience of other workers *(Flyger 1959, Edwards and Eberhardt 1967, Nixon et al. 1967,* and *Mosby 1969)* shows that this procedure underestimates the population.

The frequency-of-capture method, using linear regression procedures *(Edwards and Eberhardt 1967),* was rejected partly by inspection of the capture records for October and November. There were 48, 17, 9, and 1 fox squirrels in frequency-of-capture classes 1, 2, 3, and 4, respectively. Approximation of a minimum of 58 squirrels in the 0 frequency-of-capture class indicated a minimum November population of 133 squirrels, well above the upper confidence limit of the Lincoln Index estimate. Also, the use of the above frequency-of-capture method in an intensive long-term study of gray squirrel populations yielded estimates that were 52 to 157 percent higher than those indicated by time specific data and extensive field observations *(Mosby 1969).*

Discussion

If it is assumed that the harvest of 17 lactating females in September did not result in mortality of young in the nest, and that each of these lactating females produced an average of 2.5 squirrels *(Brown and Yeager 1945),* then the production from this source should have been about 42 squirrels. Also, 6 lactating females were livetrapped in October but were not harvested. If it is assumed that each of these females also produced an average of 2.5 squirrels, then the total production from both sources of lactating females should have been 57 summer-born squirrels. Thirty-seven summer-born squirrels were actually handled on the study area; of these, 13 were bagged in September and October and 24 others were trapped in October and November.

The harvest of 139 fox squirrels in the 68-acre woods was greater than the total kill reported for any single year from 1950 to 1966 on the 102-acre study area at the Rose Lake Wildlife Research Station in Michigan *(Queal and Fouch 1967)*. The average kill of 2.0 squirrels per acre also was greater. At Rose Lake, the highest kill of 121 squirrels (average 1.2 per acre) represented an exploitation rate of 65.4 percent, the highest rate for that area in 11 years in which prehunt populations were live-trapped. The average rate of exploitation for the 11 years was 56.1 percent.

In my study, the estimate of a population of 240 squirrels at the beginning of the hunting season requires the assumption of some stability in the population during the period 1 September to 12 November. Actually, there may have been a greater or smaller number of squirrels on 1 September, and either an increase or decrease in their number during September (for reasons other than reductions due to hunting). There is also the possibility that there was an influx of squirrels into the study area in October that partly offset the loss of squirrels through hunting. However, such questions are somewhat academic to the primary objective —to determine the effect of intensive hunting of fox squirrels on the size of the after-hunting-season population in the study area. Calculations showed that it consisted of 96 squirrels, certainly no indication of overexploitation of the population available to hunting. Even if this population estimate was not reliable, the minimum population observed in trapping in October and November was 80 squirrels.

It is likely that the level of hunting pressure applied throughout the 61-day season was greatly in excess of that usually sustained by fox squirrel populations in other areas open to hunting. Also, the efficiency of hunting probably was greater. Those who did most of the hunting were intimately familiar with the area and also had the benefit of knowing the distribution in the woods of the past kill of the current season. And the hunting effort was selective in that it was generally limited to the periods of greatest squirrel activity. There was no relaxation of hunting effort as the population declined, but only with the reduced availability of

squirrels to the gun because of unfavorable hunting conditions. It was reasonably assumed that most hunters would have sought other areas in which to hunt when hunting success dropped to the level of that of the first week of October in the study area.

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THE FOREST SERVICE of the U. S. Department of Agriculture is dedicated to the principle of multiple use management of the Nation's forest resources for sustained yields of wood, water, forage, wildlife, and recreation. Through forestry research, cooperation with the States and private forest owners, and management of the National Forests and National Grasslands, it strives — as directed by Congress — to provide increasingly greater service to a growing Nation.

THE SHOLO MILL:

Return on Investment versus Mill Design

by Hugh W. Reynolds
and Charles J. Gatchell

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NORTHEASTERN FOREST EXPERIMENT STATION, UPPER DARBY, PA.
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MANUSCRIPT RECEIVED FOR PUBLICATION 12 AUGUST 1970.

BUILD A SHOLO MILL?

THE newly developed SHOLO (from SHOrt LOg) process can be used to convert low-grade hardwood logs into parts for standard warehouse pallets and pulp chips. Should you build a SHOLO mill? This paper has been prepared to help you decide.

A detailed description of the SHOLO process and the manpower and equipment needed for one type of SHOLO mill design are given in an earlier paper (*The SHOLO mill: make pallet parts and pulp chips from low-grade hardwoods,* by Hugh W. Reynolds and Charles J. Gatchell; USDA Forest Service Research Paper NE-180, 1970).

Whether you decide to build a SHOLO mill will depend on whether it would be profitable enough. How will changes in such factors as timber quality and quantity, labor supply, interest rates, and prices for pallet parts and pulp chips affect your profits? Will changes in mill design make the process more worthwhile? A return-on-investment analysis will provide answers to questions such as these. Return on investment is the annual profit remaining after all expenses are paid; it is expressed as a percentage of the equity capital investment.

This paper presents an approach to determining return on investment for the independent producer — the businessman whose major concern is an adequate profit. But we recognize that there may be other reasons for investing in a SHOLO mill. Consider the large timber holder who is converting low-quality hardwood stands into higher yielding softwood stands. This is normally done at an initial financial loss, with the expectation of greater profits in the future. The timber holder may find that the SHOLO mill would change his losses to a small profit and therefore would be worthwhile.

Consideration of the motives behind the potential investment is beyond the scope of this report. Whatever your reasons may be for considering a SHOLO mill, the procedures contained in

this report will help you to make your decisions. By varying the values of your own unique set of factors and repeating the analysis, you will obtain an accurate picture of the range of profits that can be expected.

PROCEDURE FOR DETERMINING THE RETURN ON INVESTMENT

To illustrate the procedural steps in determining the return on investment, we based our examples on the SHOLO mill described in our earlier report. Before a determination can be started, twelve basic factors must be known or estimated:

Item	*Example value*
1. Daily pallet-part production rate	16 MBF
2. Pallet-part selling price	$128/MBF
3. Pulp-chip selling price	$7/ton
4. Long-log potential[1]	57 percent
5. SHOLO-log potential[2]	28 percent
6. Number of employees and wage rates	20 men @ $2.50/hour 3 men @ $3.50/hour
7. Total capital investment	$550,000
8. Equity capital	$300,000
9. Borrowed capital	$250,000
10. Depreciation schedule	Straight line
11. Interest rates:	
a. Borrowed capital	8 percent
b. Sinking fund	6 percent
12. Percentage of income for operations[3]	20 percent

$$[1]\text{Long-log potential} = \frac{\text{Weight of SHOLO logs}}{\text{Weight of representative sample of long logs}} \times 100$$

$$[2]\text{SHOLO-log potential} = \frac{\text{Weight of pallet parts}}{\text{Weight of representative sample of SHOLO logs}} \times 100$$

[3]Money based on the percentage of income for operations is used to cover such items as employee fringe benefits, electric power, phone bills, and other overhead items. It will cover all expenses not specifically listed on worksheet 1,

The long-log potential and the SHOLO-log potential should be determined from pilot-plant tests of representative samples of raw material.

There are many ways to make financial plans for building a SHOLO mill. In our example we have assumed that:

- The total capital investment ($550,000) will be made up in part by owner's equity ($300,000); the remainder will be borrowed capital ($250,000).
- The land on which the mill is built will not depreciate and will be used as collateral for a loan ($20,000) to cover its purchase price. The only cost of the land will be the interest (8 percent) on this loan.
- The life of the plant will be 10 years, at the end of which there is no salvage value.
- The depreciation schedule is straight line.
- The borrowed capital ($250,000) will be raised by the sale of a bond at 8 percent interest, maturing in 10 years.
- A 10-year sinking fund will be established to accumulate the money to retire the bond ($250,000) and pay back the owner's equity ($300,000). As this money is really a form of savings, it will earn interest (6 percent) that will be used to reduce the principal payments to the sinking fund.
- The return on investment will be the annual profit that the owner will receive for the use of his equity capital ($300,000).

THE NOMOGRAM CHARTS

We have devised a set of nomogram charts that you can use to determine the values you will need to know. The nomogram consists of three scales. Plot the two known values on their respective scales; lay a straightedge across them; and the point where the straightedge crosses the third scale will give you the unknown value you need.

Though the nomogram is subject to estimation errors (you have to interpolate when the line falls between two marks on the scale), it is precise enough to allow an accurate evaluation of particular choices of SHOLO mill design and production and financial factors.

Normally, investors will start with what is for them the best combination of factors. Often it will be necessary to make adjustments in these factors to end up with a realistic combination. The use of the nomograms will enable the SHOLO mill designer and the prospective SHOLO mill owner to arrive at a common understanding. The owner will be interested in varying all factors to arrive at the best profit or return on investment. The designer will be interested in developing a well-balanced production operation that will satisfy the owner's profit requirements.

By visually showing the relationship between factors, nomograms help to avoid the necessity for repeated mathematical calculations and to focus on the factors themselves. When a set of acceptable factors is found that give the desired rate of return on investment, a more precise analysis by conventional accounting methods should be made.

A WORD OF CAUTION: Several of the nomograms are based on specific assumptions. If the assumptions are changed, these nomograms cannot be used with accuracy. For example, charts 1, 6, and 8 are based on 225 production-days per calendar year. Chart 2 is based on hardwood species that yield green pallet parts weighing 2 tons per MBF. If you wish to use different assumptions, calculate the values at that point and proceed on with the other nomograms.

CALCULATING THE RETURN ON INVESTMENT

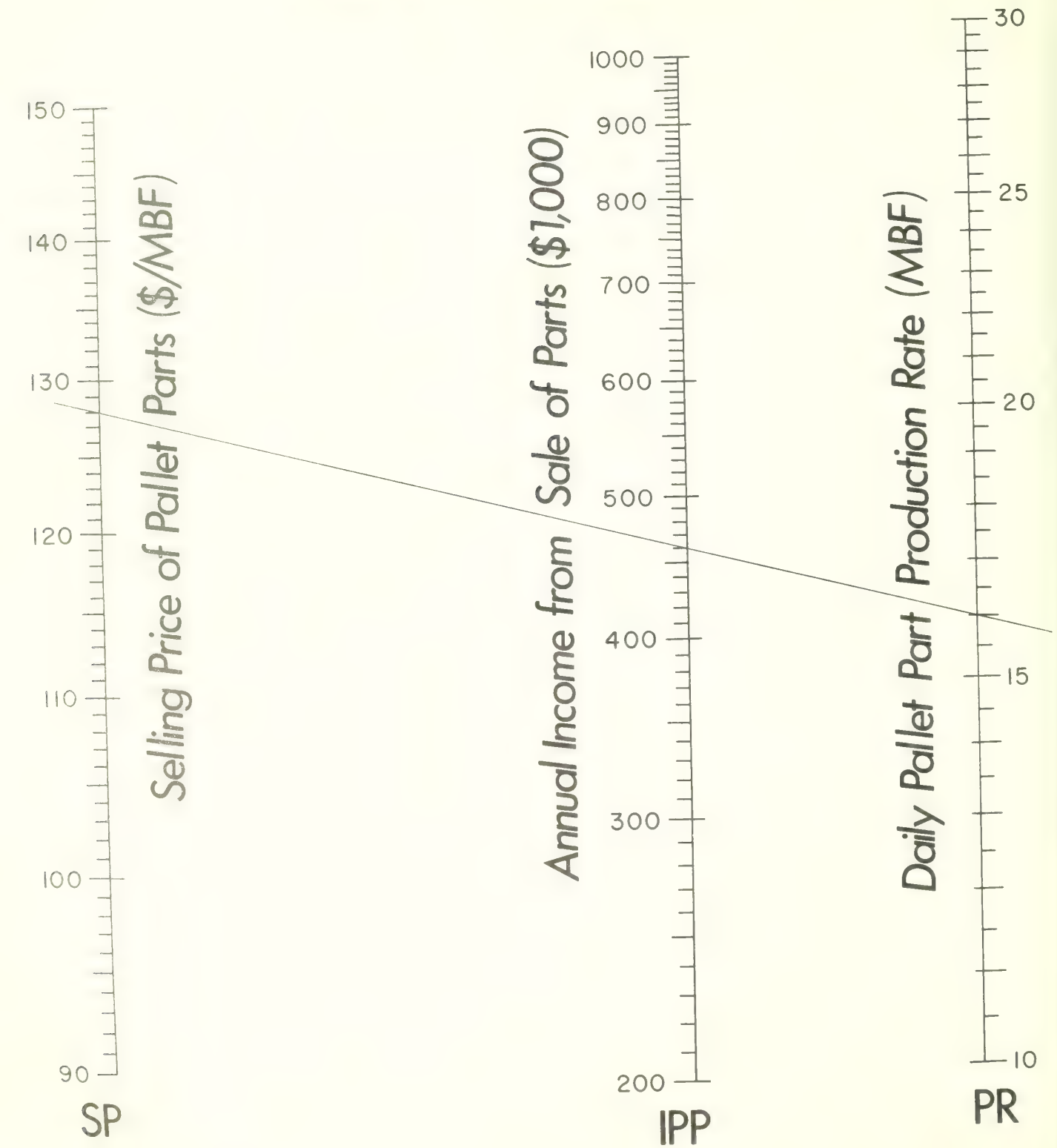
The method for determining return on investment is given in a series of steps, one for each value factor. For each step, the nomogram to be used is on the left-hand page. On the facing page you will find: (1) the assumption on which the nomogram is based; (2) the procedure to be followed, given without reference to specific values; and (3) an example showing how the value is derived from the nomogram.

At the back of the book (page xx) is a fold-out sample worksheet that shows how the individual values can be recorded for calculating the return on investment. When the worksheet is folded out, you will have before you (1) the nomogram, (2) the page of instructions, and (3) the worksheet on which each value factor is entered for the example used.

Blank worksheets are attached that you can use for determining value factors for conditions other than those used in the examples.

Annual Income from Sale of Pallet Parts for 225 Production Days Per Year

$$IPP = SP \times 225 \times PR \times .001$$



STEP 1.
ANNUAL INCOME FROM SALE OF PALLET PARTS

Assumption: 225 production-days per year.

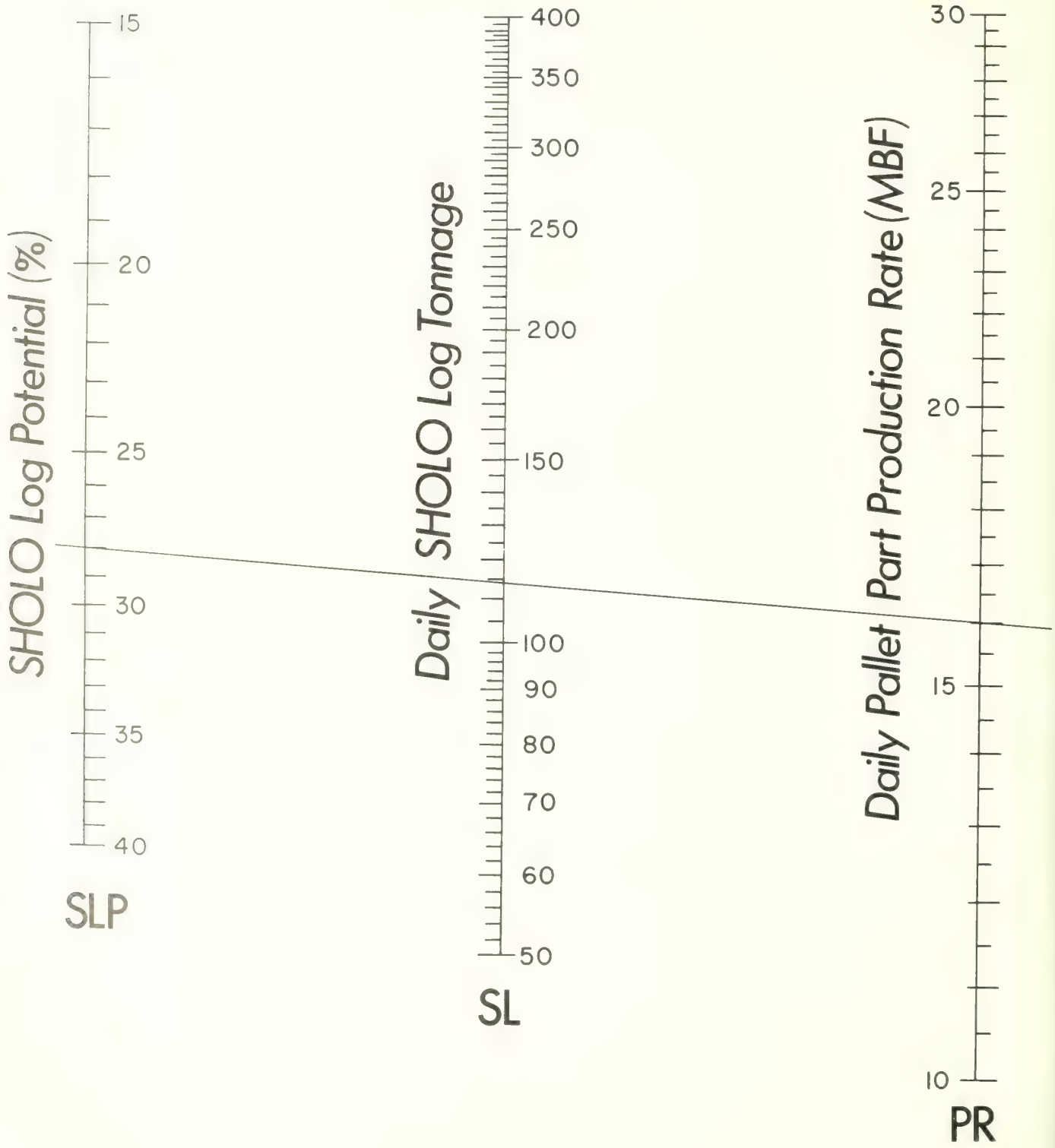
Procedure:

1. Decide on the required or desired daily pallet-part production rate in terms of MBF/day. Enter this value as item 1 on the worksheet.
2. Next decide on the required or desired selling price per MBF for the pallet parts. Enter this value as item 2 on the worksheet.
3. Using chart 1, mark the selling price (SP) of pallet parts on the SP scale. Mark the daily production rate (PR) value on the PR scale. With a straightedge connect these two marks. Read the income from the sale of parts where the line crosses the IPP scale. Enter this value as item 22 on the worksheet.
4. Proceed to step 2.

Example:

Daily pallet parts production rate is:	16 MBF
Selling price of finished green pallet part is:	$128/MBF
Annual income from the sale of pallet parts is read as:	$460,000

Daily Tonnage of SHOLO Logs for Pallet Parts Weighing 2 Tons/MBF SL=200 PR/SLP



STEP 2.

DAILY TONNAGE OF SHOLO LOGS

Assumption: Green pallet parts weigh 2 tons per MBF. This is valid for such hardwoods as oaks, beech, pecan hickory, white ash, and sugar maple.

Procedure:

1. Enter the SHOLO-log potential as item 3 on the worksheet. Based on a representative sample of SHOLO logs, the SHOLO-log potential equals

$$\frac{\text{Total weight of pallet parts}}{\text{Total weight of SHOLO logs}} \times 100.$$

2. Using chart 2, mark the SHOLO-log potential on the SLP scale. Mark the daily pallet part production rate (item 1 on the worksheet) on the PR scale. With a straightedge connect these two marks. Read the required SHOLO-log quantity from the SL scale. Enter this value as item 4 on the worksheet.

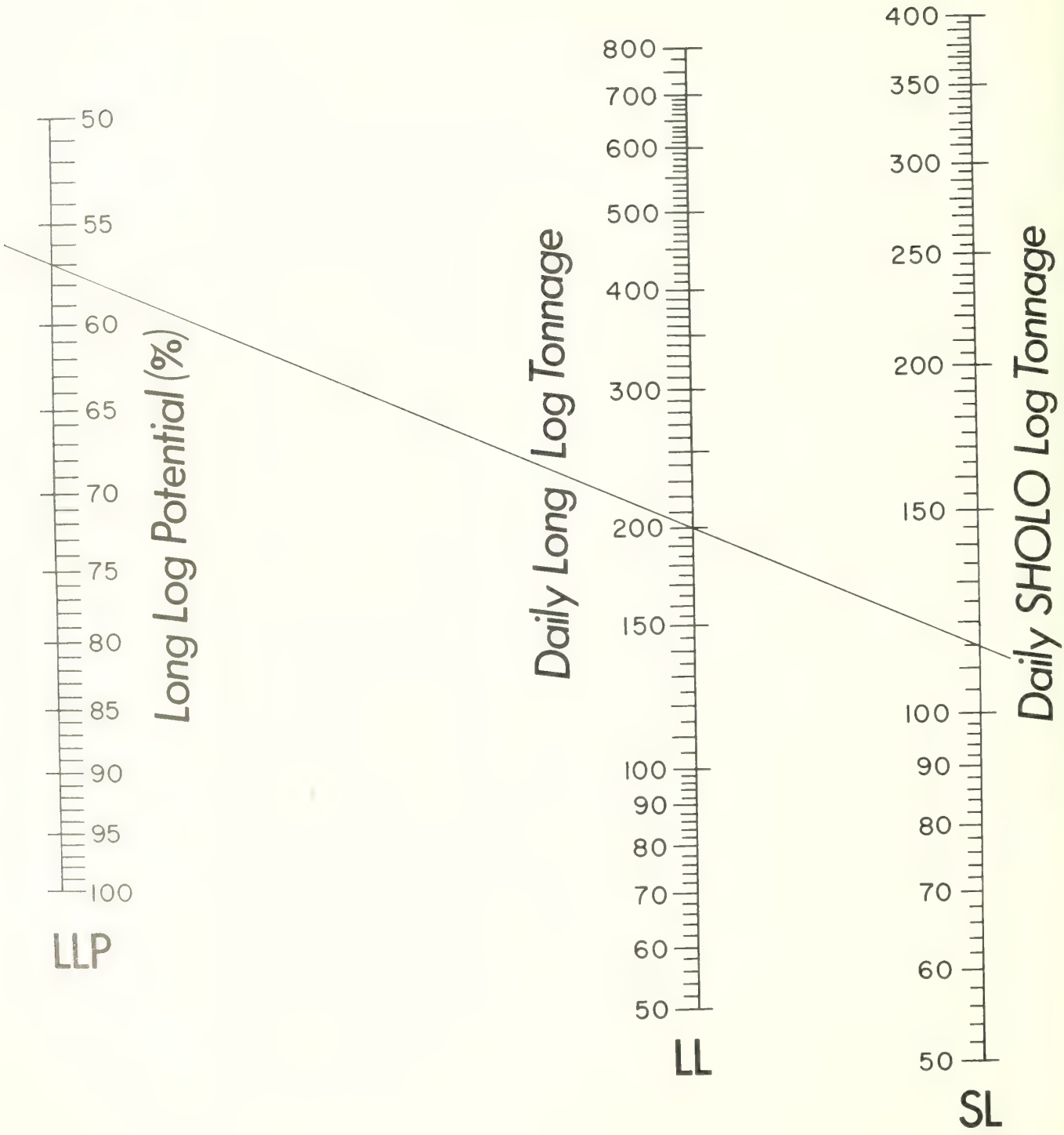
3. Proceed to step 3.

Example:

SHOLO-log potential is:	28 percent
Daily pallet-part production rate is:	16 MBF
Daily SHOLO-log tonnage is read as:	114 tons/day

Daily Long Log Tonnage

$$LL = \frac{SL \times 100}{LLP}$$



STEP 3.
DAILY LONG-LOG TONNAGE

Assumption: None.

Procedure:

1. Enter the long-log potential as item 5 on the worksheet. Based on a representative sample of long logs, the long-log potential equals

$$\frac{\text{Total weight of SHOLO logs}}{\text{Total weight of long logs}} \times 100.$$

2. Using chart 3, mark the long-log potential on the LLP scale. Mark the SHOLO log tonnage (item 4 on the worksheet) on the SL scale. With a straightedge connect these two marks. Read the required daily long-log tonnage from the LL scale. Enter this value as item 6 on the worksheet.

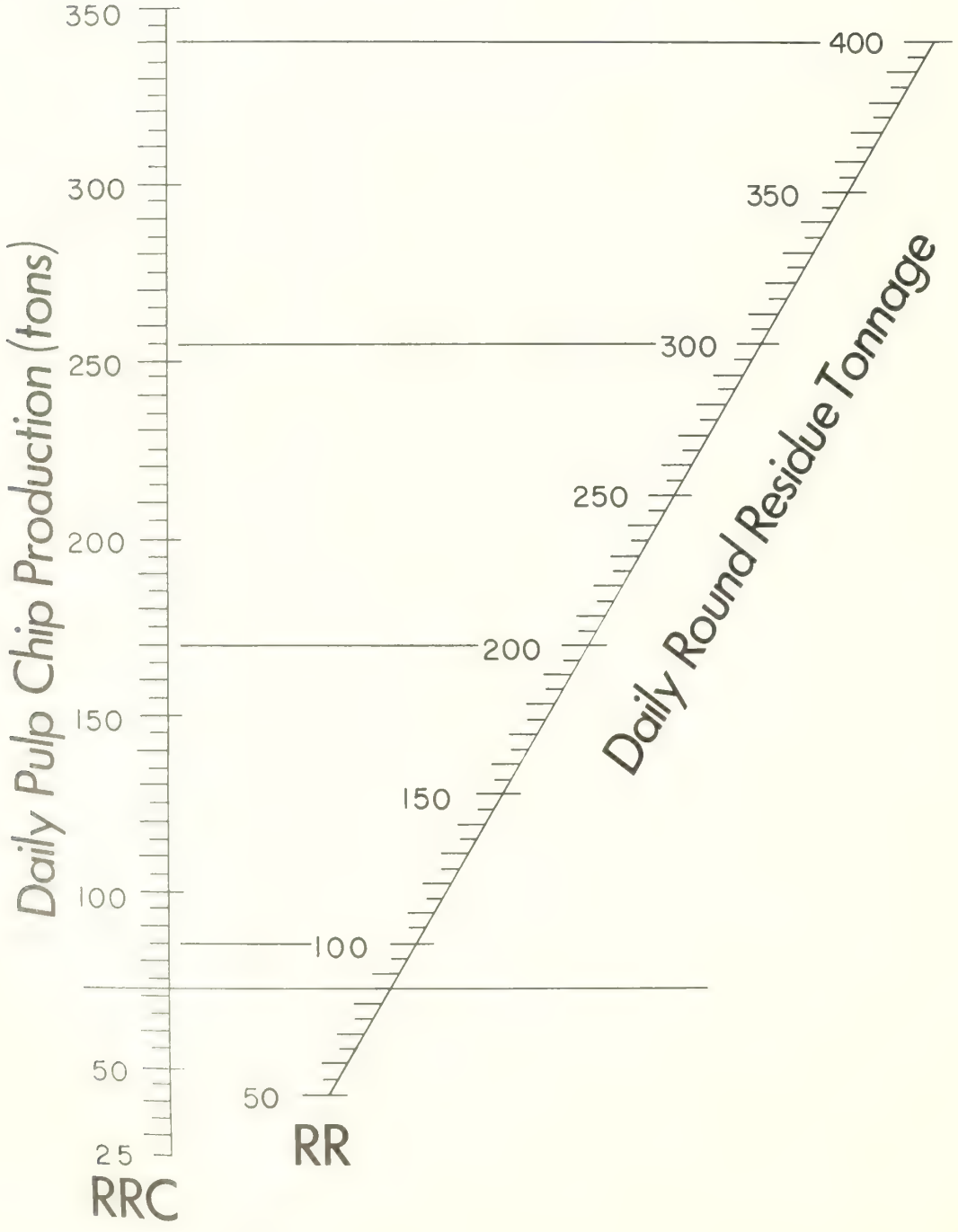
3. Proceed to step 4.

Example:

Long-log potential is:	57 percent
SHOLO-log tonnage is:	114 tons/day
Long-log tonnage is read as:	200 tons/day

Daily Pulp Chip Production from Round Residue for 85% Yield by Weight

RRC = 0.85 RR



STEP 4.
DAILY PULP-CHIP PRODUCTION FROM ROUND RESIDUE

Assumption: The chipping of round residue yields 85 percent by weight of pulp chips and 15 percent by weight of waste.

Procedure:

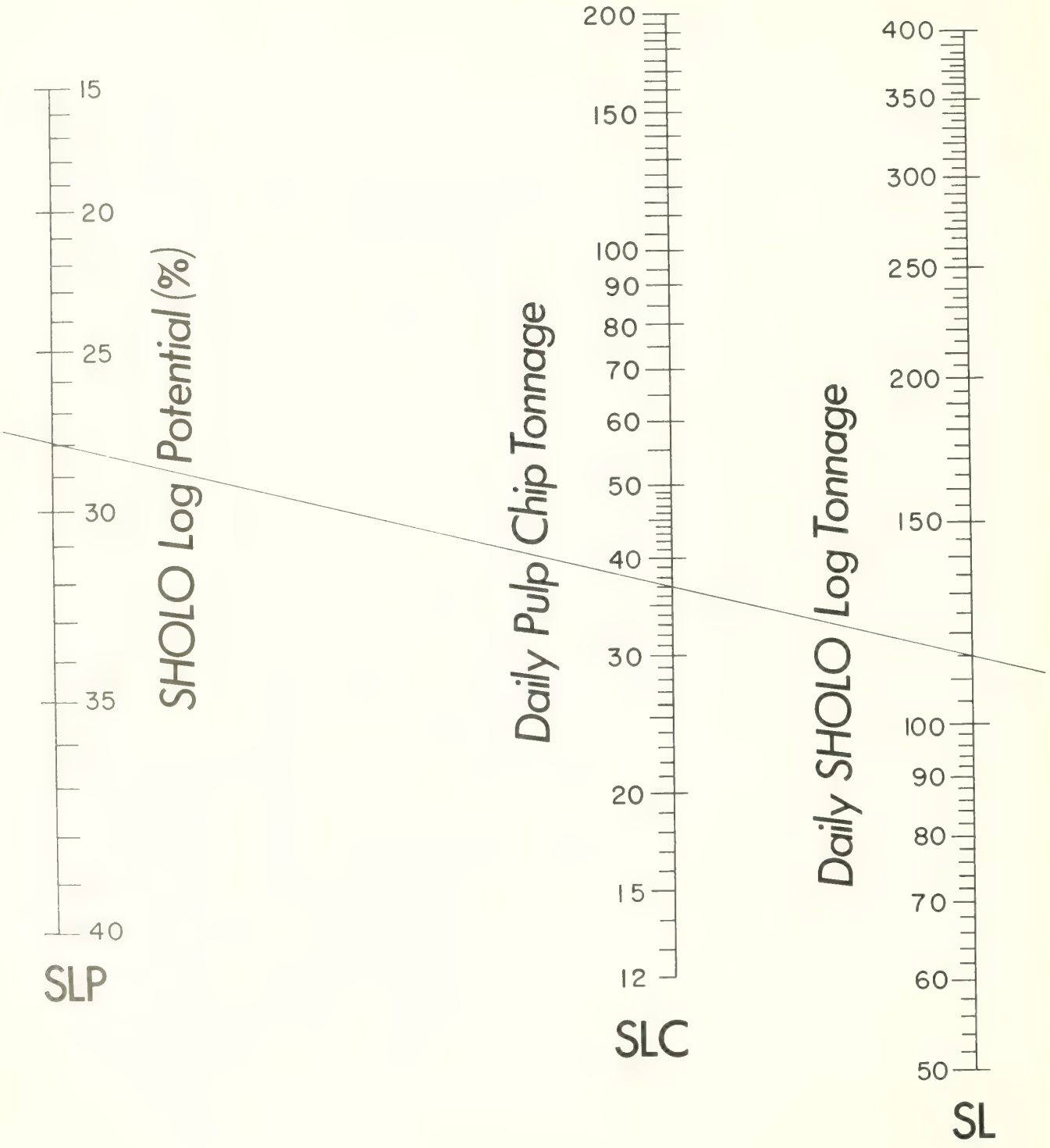
1. Determine the daily tonnage of round residue by subtracting item 4 (SHOLO-log tonnage) from item 6 (long-log tonnage). Enter the daily round-residue tonnage as item 7.
2. Using chart 4, mark the round residue quantity on the RR scale. With a straightedge mark a horizontal line to the RRC scale. Enter the value read on the RRC scale as item 8 on the worksheet.
3. Proceed to step 5.

Example:

Long-log tonnage is:	200 tons/day
SHOLO-log tonnage is:	114 tons/day
Round-residue tonnage = 200 — 114 =	86 tons/day
Daily pulp-chip production is read as:	74 tons/day

Daily Pulp Chip Tonnage from SHOLO Log Residue

$$SLC = \frac{SL \times (60 - SLP)}{100}$$



STEP 5.
DAILY CHIP PRODUCTION FROM SHOLO-LOG RESIDUE

Assumption: Sixty percent of the weight of the SHOLO logs is convertible into finished pallet parts and pulp chips. The remaining 40 percent is attributed to bark, sawdust, planer shavings, and short-end trim pieces.

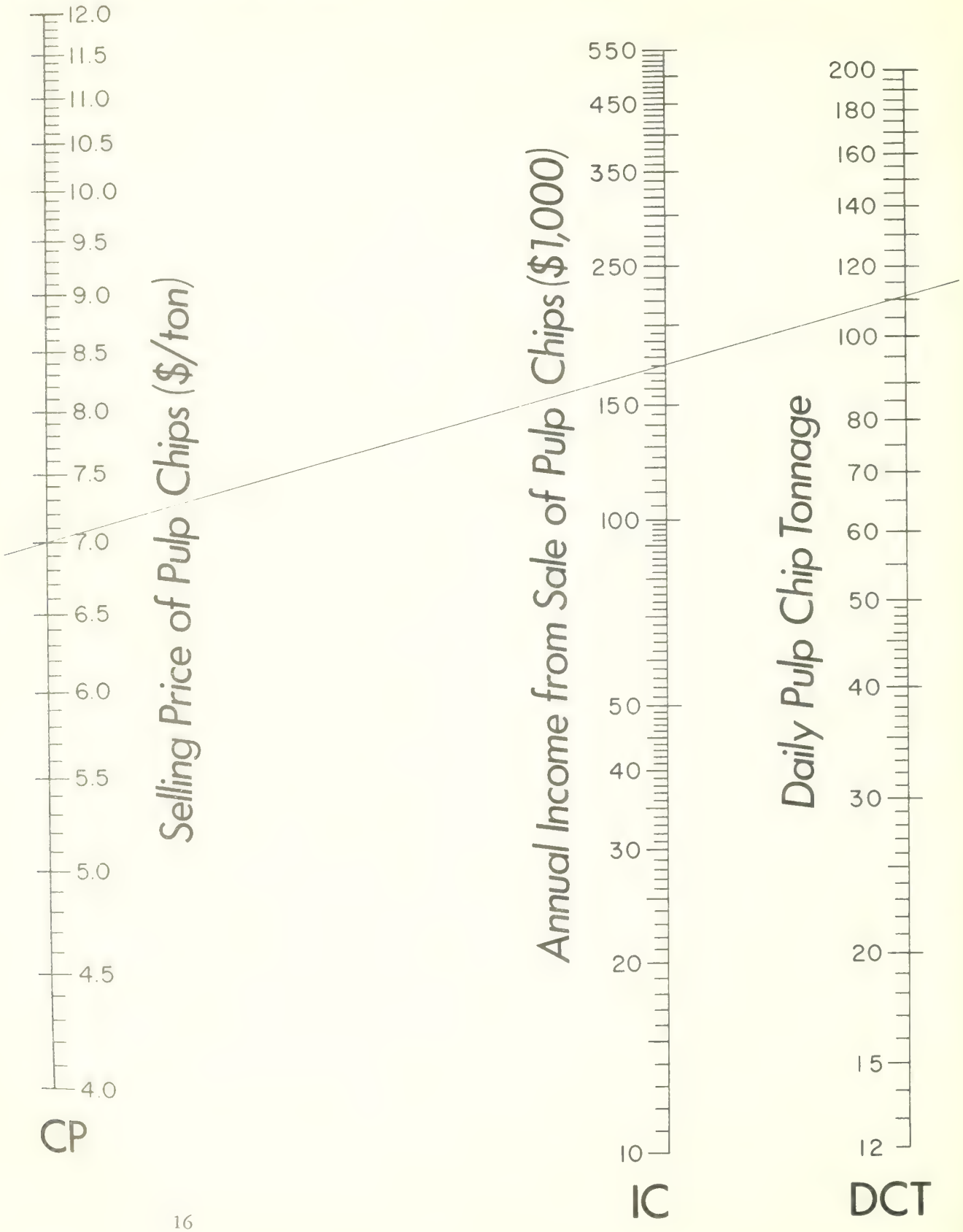
Procedure:

1. Using chart 5, mark the SHOLO-log potential (item 3) on the SLP scale. Mark the SHOLO-log tonnage (item 4) on the SL scale. With a straightedge connect these two marks. Read the daily pulp-chip tonnage from the SLC scale and enter this value as item 9 on the worksheet.
2. Proceed to step 6.

Example:

SHOLO-log potential is:	28 percent
SHOLO-log tonnage is:	114 tons/day
Chip production from SHOLO-log residue is read as:	37 tons/day

Annual Income from Sale of Pulp Chips for 225 Production Days per Year IC = DCT x 225 x CP x 0.001



STEP 6.
ANNUAL INCOME FROM THE SALE OF PULP CHIPS

Assumption: 225 production-days per year.

Procedure:

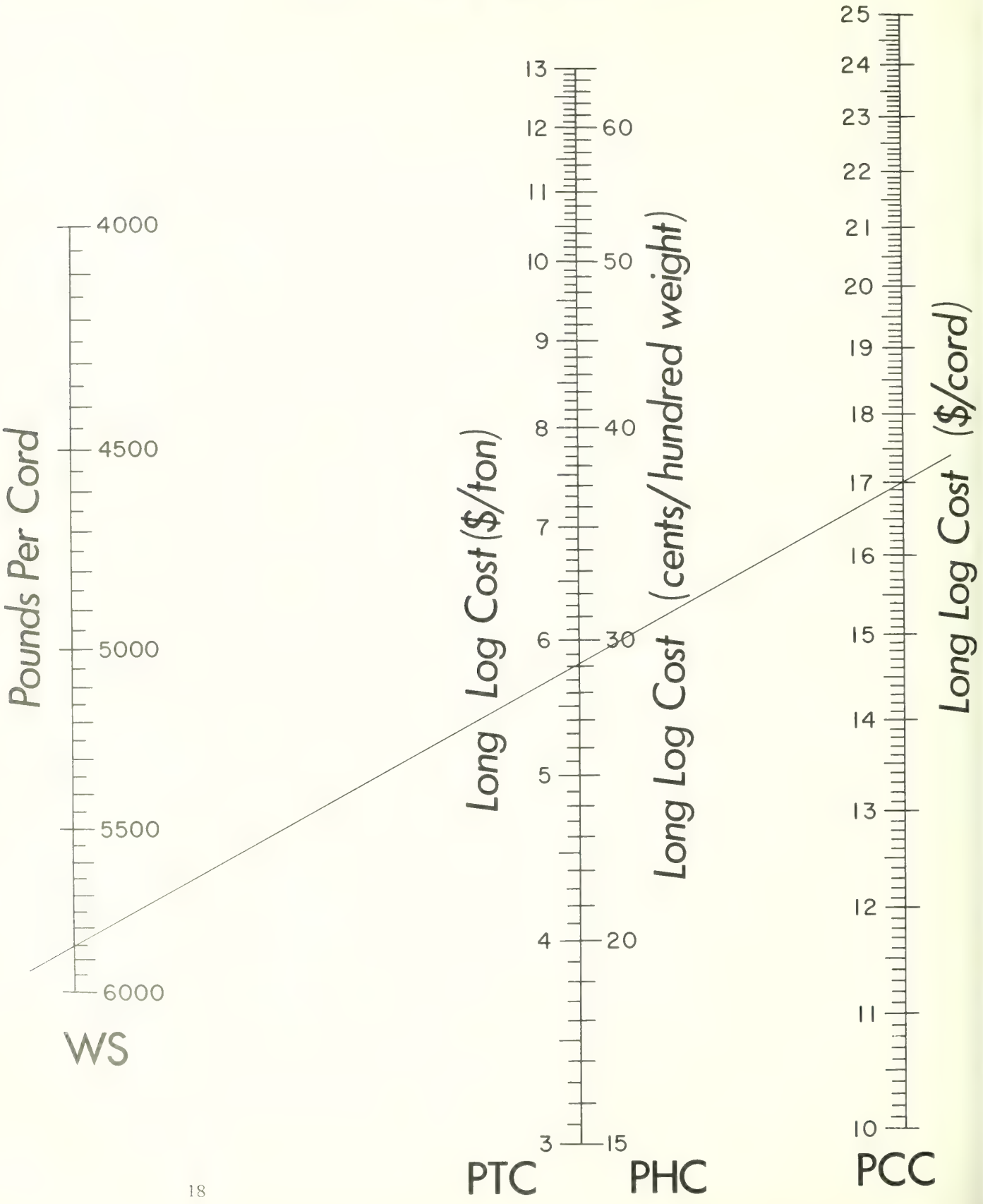
1. Determine the total daily pulp-chip tonnage by adding item 8 (pulp chips from round residue) and item 9 (pulp chips from SHOLO logs). Enter this total as item 10.
2. Enter the selling price (f.o.b. the SHOLO mill) for green pulp chips as item 11 on the worksheet.
3. Using chart 6, mark the pulp-chip selling price (item 11) on the CP scale. Mark the total daily pulp-chip tonnage (item 10) on the DCT scale. Read the annual income from the sale of pulp chips on the IC scale and enter this value as item 23 on the worksheet.
4. Proceed to step 7.

Example:

Pulp-chip selling price is:	$7/ton
Pulp-chip yield from round residue is:	74 tons/day
Pulp-chip yield from SHOLO logs is:	37 tons/day
Total daily pulp-chip tonnage = 74 + 37 =	111 tons/day
The annual income from the sale of pulp chips is read as:	$175,000

Long Log Cost Per Ton

PTC=PCC x 2000/WS



STEP 7.
LONG-LOG COST PER TON

Assumption: None.

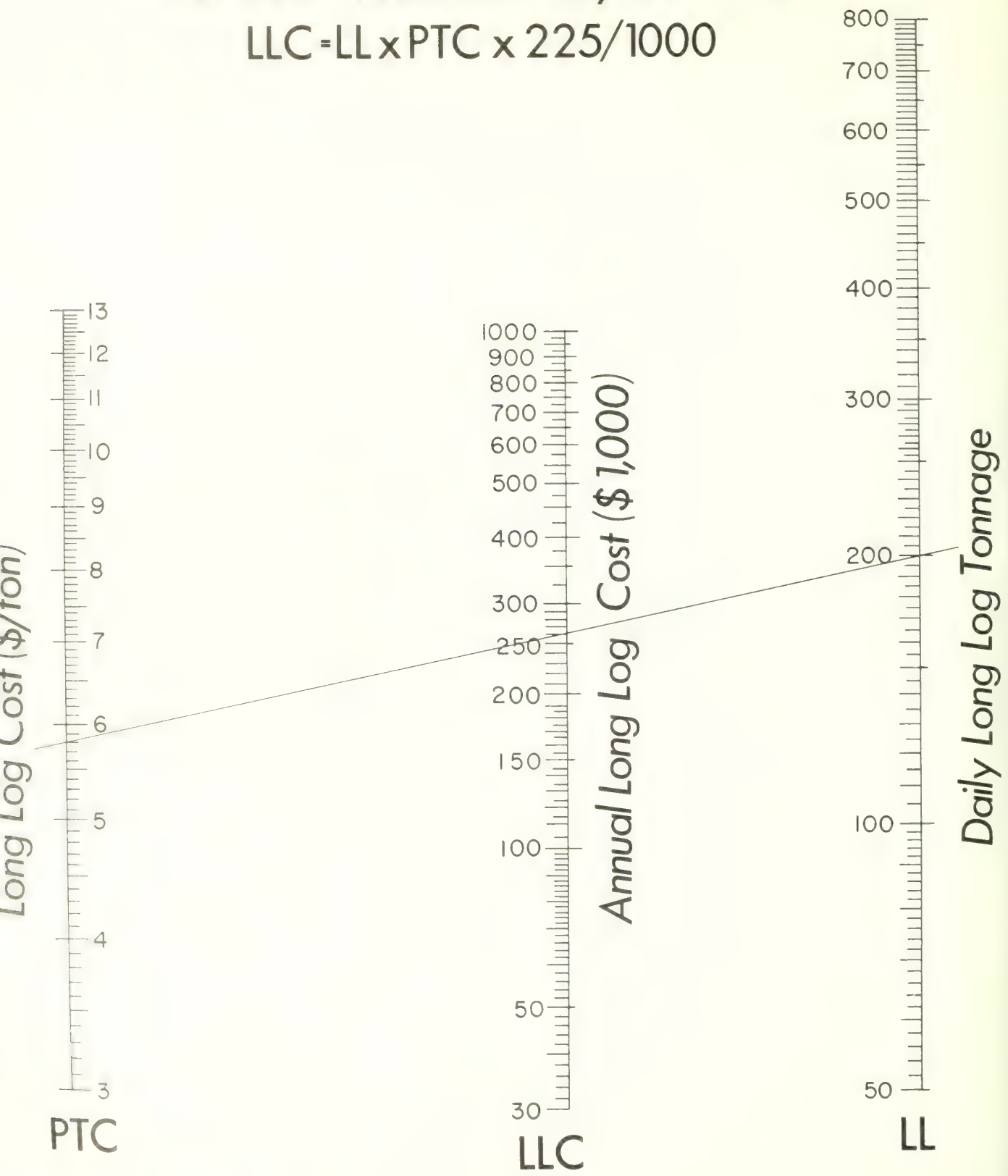
Procedure:

1. When the long-log costs are stated in dollars per ton, enter this value as item 13 and proceed to step 8.
2. When log costs are stated in dollars per cord or dollars per hundredweight, proceed as follows:
    a. Dollars per cord: First, determine the weight scaling factor or how many pounds of long logs make a cord. Enter this as item 12 on the worksheet. Next, determine the long-log cost per cord. Using chart 7, mark the weight scaling factor on the WS scale. Enter the log cost per cord on the PCC scale. With a straightedge connect the two marks. Read the log cost per ton from the PTC scale. Enter this value as item 13 on the worksheet.
    b. Dollars per hundredweight: If the log costs are in dollars per hundredweight, the cost in dollars per ton may be read directly by comparing values on the PHC and PTC scales. Enter the long-log cost per ton as item 13 on the worksheet.
3. Proceed to step 8.

Example:

Weight scaling factor is:	5,850 lbs./cord
Estimated long-log price per cord is:	$17
Long-log cost per ton is read as:	$5.80

Annual Long Log Cost
for 225 Production Days Per Year
LLC = LL x PTC x 225/1000



STEP 8.
ANNUAL LONG-LOG COST

Assumption: 225 production-days per year.

Procedure:

1. Using chart 8, mark the long-log cost per ton (item 13) on the PTC scale. Mark the daily long-log tonnage (item 6) on the LL scale. With a straightedge connect the two marks. Read the annual long-log cost on the LLC scale and enter the value as item 26 on the worksheet.
2. Proceed to step 9.

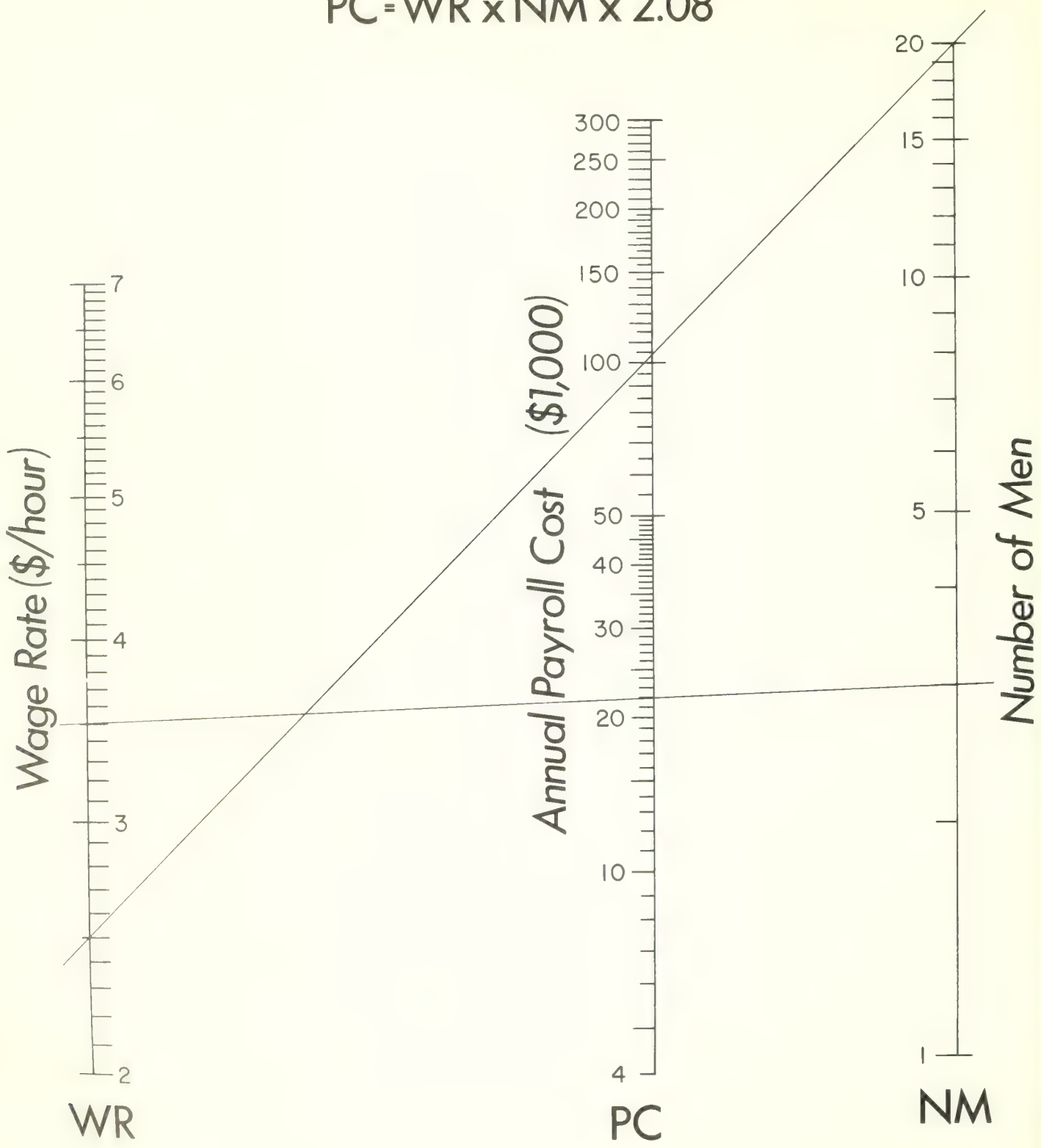
Example:

Long-log cost per ton is:	$5.80
Daily long-log tonnage is:	200 tons/day
Annual long-log cost is read as:	$263,000

Annual Payroll Costs

for 40 Hour Work Week and 52 Week Work Year

PC = WR x NM x 2.08



STEP 9.
ANNUAL PAYROLL COSTS

Assumption: Each employee will work 40 hours per week and will be paid for 52 weeks per year, including vacation and sick-leave time.

Procedure:

1. Determine the number of men to be employed and their average wage rates. Enter these values as item 14 on the worksheet.
2. Using chart 9, enter the number of men employed at a given annual wage rate on the NM scale. If more than 20 men are employed at a given average wage rate, the total can be divided into two smaller numbers. Enter the wage rate on the WR scale. With a straightedge read the annual payroll cost on the PC scale. Repeat for each different grouping of men and wage rates. Enter the total annual payroll costs as item 27 on the worksheet.
3. Proceed to step 10.

Example:

20 men at an hourly wage rate of $2.50:	$103,000
3 men at an hourly wage rate of $3.50:	$ 22,000
Total annual payroll cost ($103,000 + $22,000)	$125,000

STEP 10.
LISTING FINANCIAL VARIABLES

Procedure:

1. List the financial variable in part II of the worksheet.
2. Proceed to step 11.

Example:

Item No.		
15	Capital investment (total):	$550,000
16	Equity capital:	300,000
17	Borrowed capital:	250,000
18	Interest rate on borrowed capital:	8%
19	Interest rate on sinking fund:	6%
20	Percentage of income reserved for operations:	20%
21	Depreciation schedule:	Straight line

STEP 11.
DETERMINING TOTAL ANNUAL INCOME

Procedure:

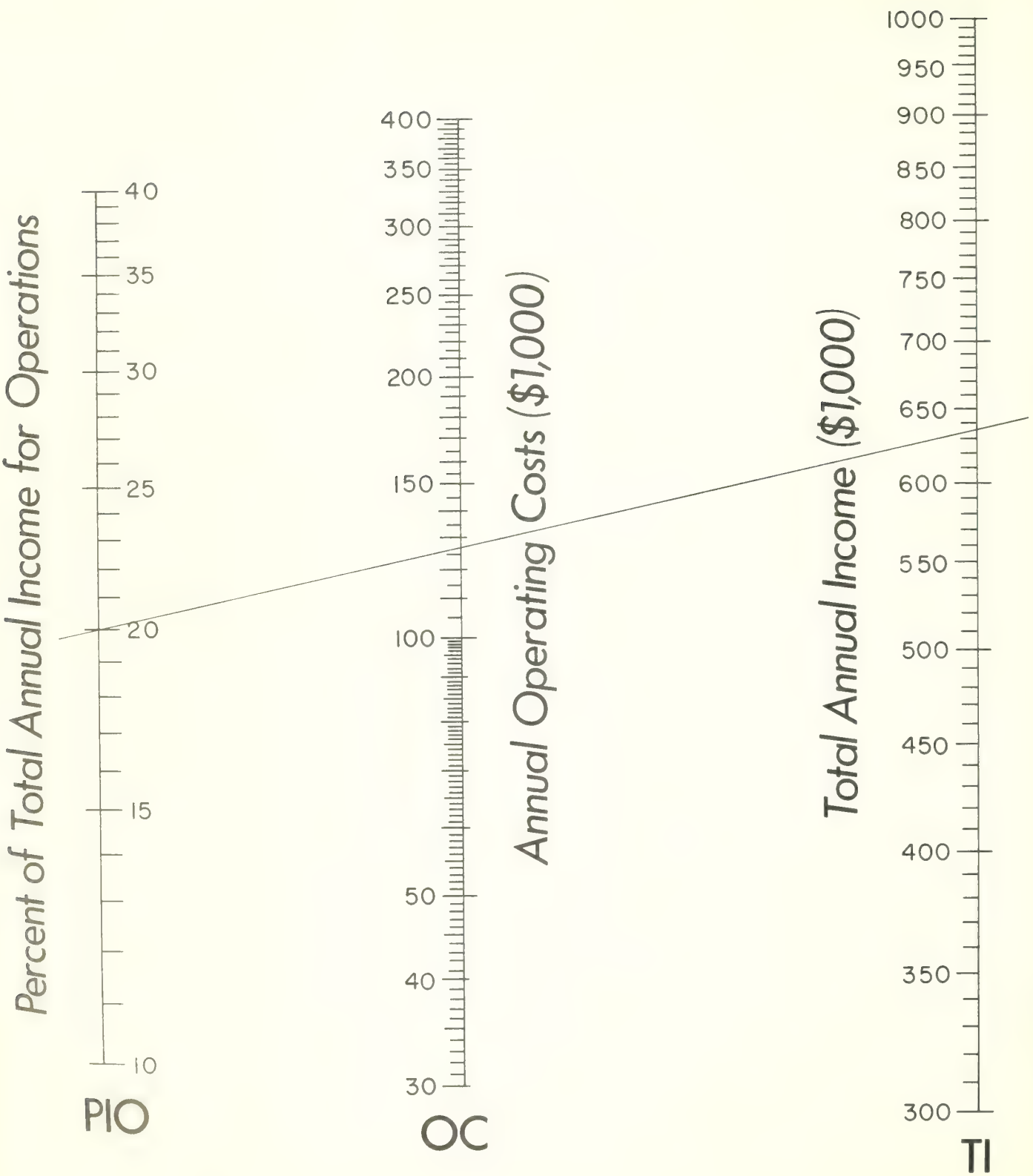
1. Add the sources of income (items 22, 23, and 24) and enter the total as item 25. It may be possible to convert some of the SHOLO mill residue into income-producing products. For example, 12 percent by weight of red oak logs is bark. With a daily input of 200 tons of long logs, 24 tons of bark per day are available for conversion into mulch. If any of the bark or other waste can be sold, the additional income is entered as item 24.
2. Proceed to step 12.

Example:

Sale of pallet parts:	$460,000
Sale of pulp chips:	$175,000
Additional sales:	0
Total annual income:	$635,000

Annual Operating Costs

OC = TI x PIO/100



STEP 12.
ANNUAL OPERATING COSTS

Assumption: None.

Procedure:

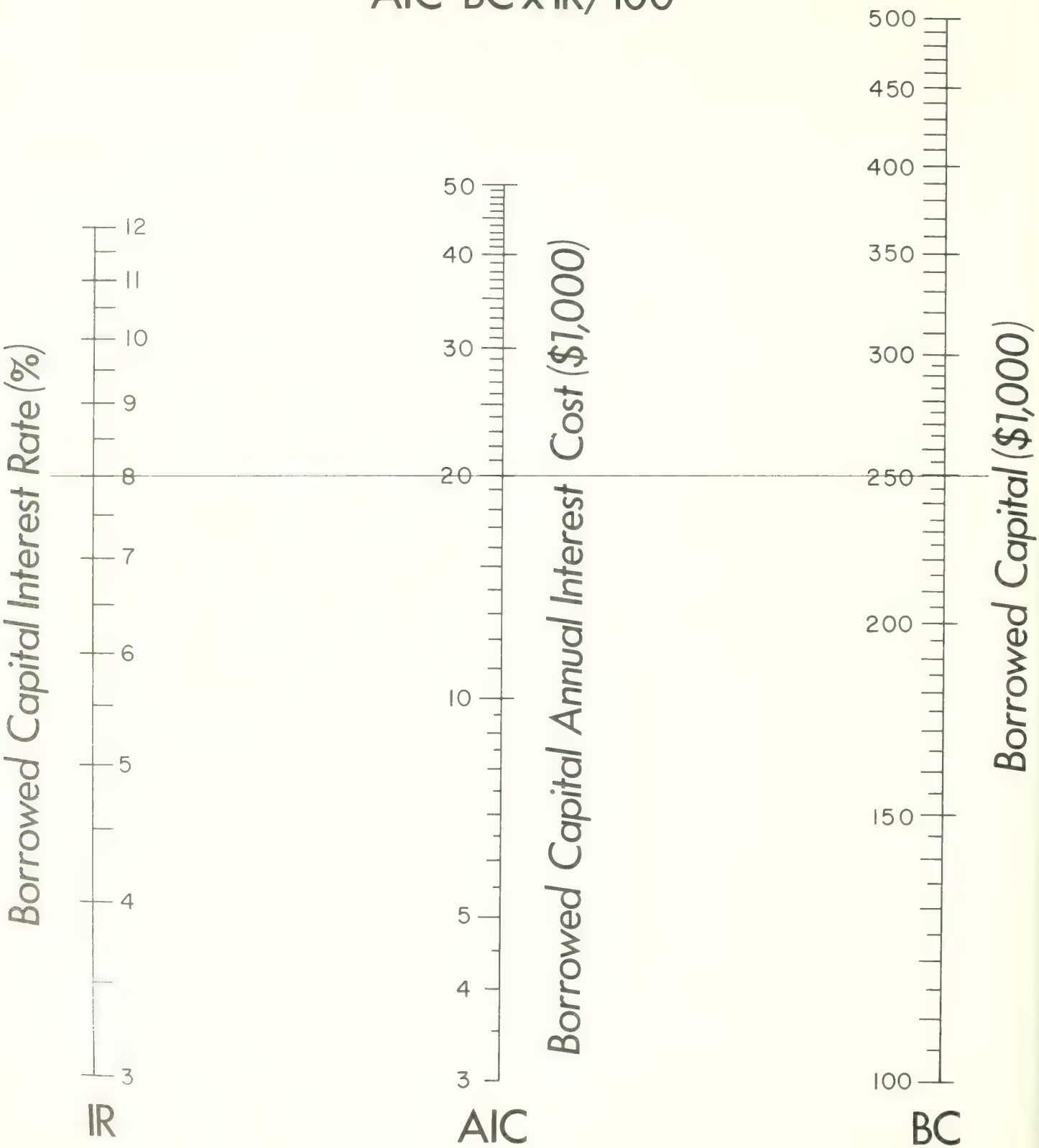
1. Using chart 10, enter the percentage of total income for operating costs (item 20) on the PIO scale. Then enter the total income (item 25) on the TI scale. With a straightedge connect these two marks. Read the operating costs on the OC scale and enter this value as item 28 on the worksheet.
2. Proceed to step 13.

Example:

Percentage of total annual income reserved for operation:	20%
Total annual income:	$635,000
Annual operating costs is read as:	127,000

Borrowed Capital Annual Interest Cost

AIC = BC x IR/100



STEP 13.
ANNUAL INTEREST COST

Assumption: None.

Procedure:

1. The interest cost is the charge for borrowed capital. In this example, we have assumed an interest rate of 8 percent (item 18) on both the bond that was used to raise $250,000 and the land, which was valued at $20,000. Interest on the land is computed at $1,600 per year; and this is entered as item 29. For interest on amounts over $100,000, chart 11 is used. Enter the interest rate (item 18) on the IR scale and the borrowed capital amount (item 17) on the BC scale. With a staightedge connect these two marks. Read the interest cost from the AIC scale and enter this value as item 30.
2. Proceed to step 14.

Example:

Land interest (0.08 x 20,000):	$ 1,600
Borrowed capital amount for bond:	250,000
Interest rate:	8%
Bond interest cost is read as:	20,000

STEP 14.
DETERMINATION OF TAXABLE INCOME

Procedure:

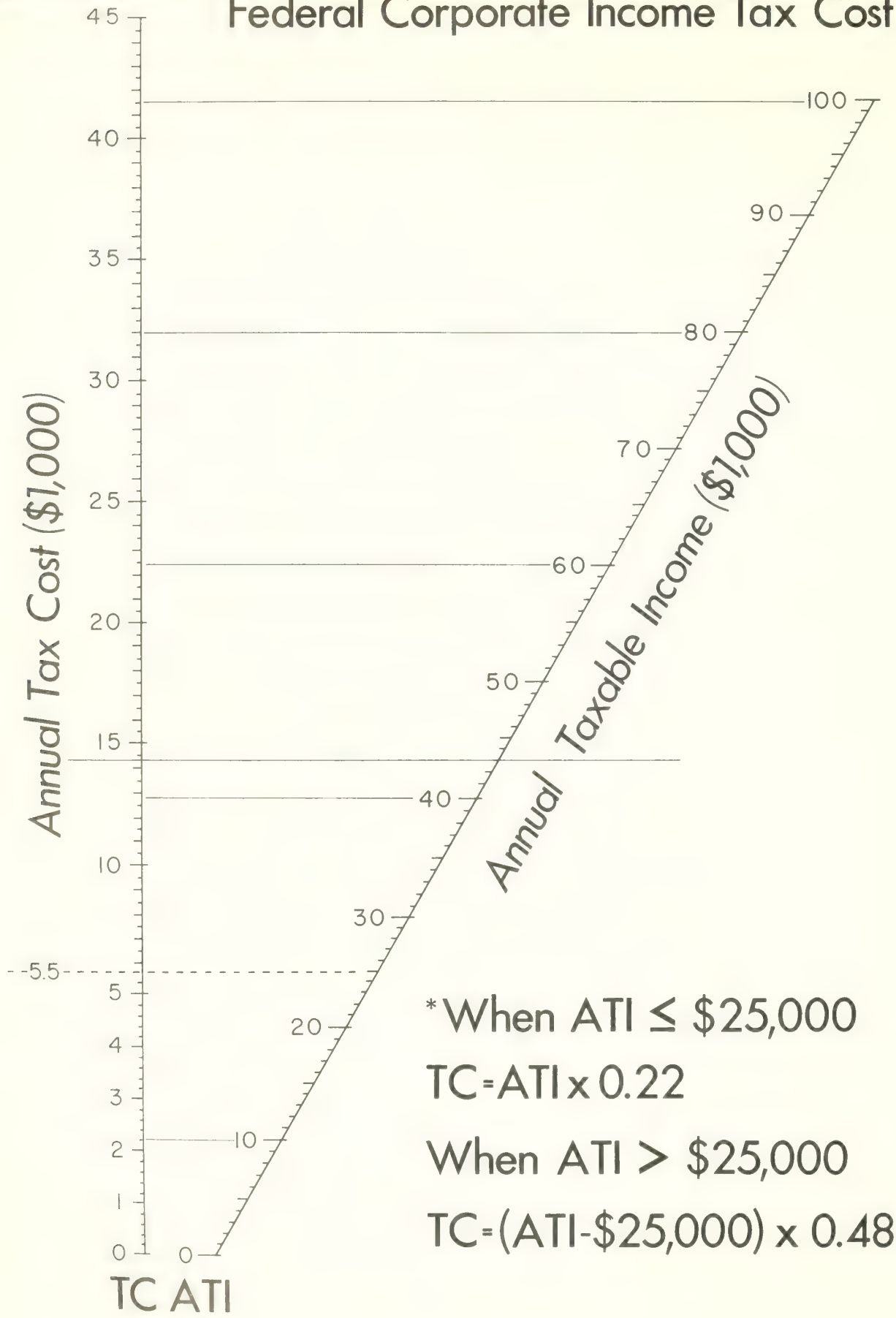
Taxable income is the total income (item 25) less expenses for logs (item 26), payroll (item 27), operations (item 28), land and bond interest charges (items 29 and 30), and annual depreciation. In our example, we used a straight-line depreciation schedule (item 20) and a 10-year plant life. Annual depreciation is, therefore, 10 percent of the total capital investment of $550,000 (item 15) or $55,000.

1. Add expense items 26, 27, 28, 29, 30, and enter the subtotal as item 31.
2. Enter the annual depreciation as item 32 on the worksheet.
3. Add items 31 and 32 and enter the total costs for tax purposes as item 33.
4. Subtract total costs for tax purposes (item 33) from the total income (item 25) and enter this as taxable income (item 34).
5. Proceed to step 15.

Example:

Taxable income (total annual income — total costs for tax purposes = $635,000 — $592,000):	$43,000

Federal Corporate Income Tax Cost*



*When ATI ≤ $25,000

TC=ATI x 0.22

When ATI > $25,000

TC=(ATI-$25,000) x 0.48 + $5,500

STEP 15.
ANNUAL FEDERAL TAX COSTS

Assumption: Tax rate is 22 percent on taxable income up to and including $25,000. Tax rate is 48 percent for taxable income over $25,000. State and local taxes are not included.

Procedure:

1. For annual taxable incomes of $100,000 or less:
   a. Using chart 12, enter the taxable income (item 34) on the ATI scale. With a straightedge draw a horizontal line from that point to the TC scale. Read the tax cost from the TC scale and enter this value as item 35 on the worksheet.
2. For annual taxable incomes above $100,000:
   a. Compute the annual tax cost, using the formula:
   $TC = (ATI - \$25{,}000) \times 0.48 + \$5{,}500$
   where

TC = annual tax cost in dollars.

ATI = annual taxable income in dollars.

CAUTION: Do not try to use chart 12 by dividing the annual taxable income into two or more subtotals. The annual tax costs that result will not add up to the actual tax costs. As an example, two times the tax cost for an income of $50,000 does not equal the tax cost for an income of $100,000.

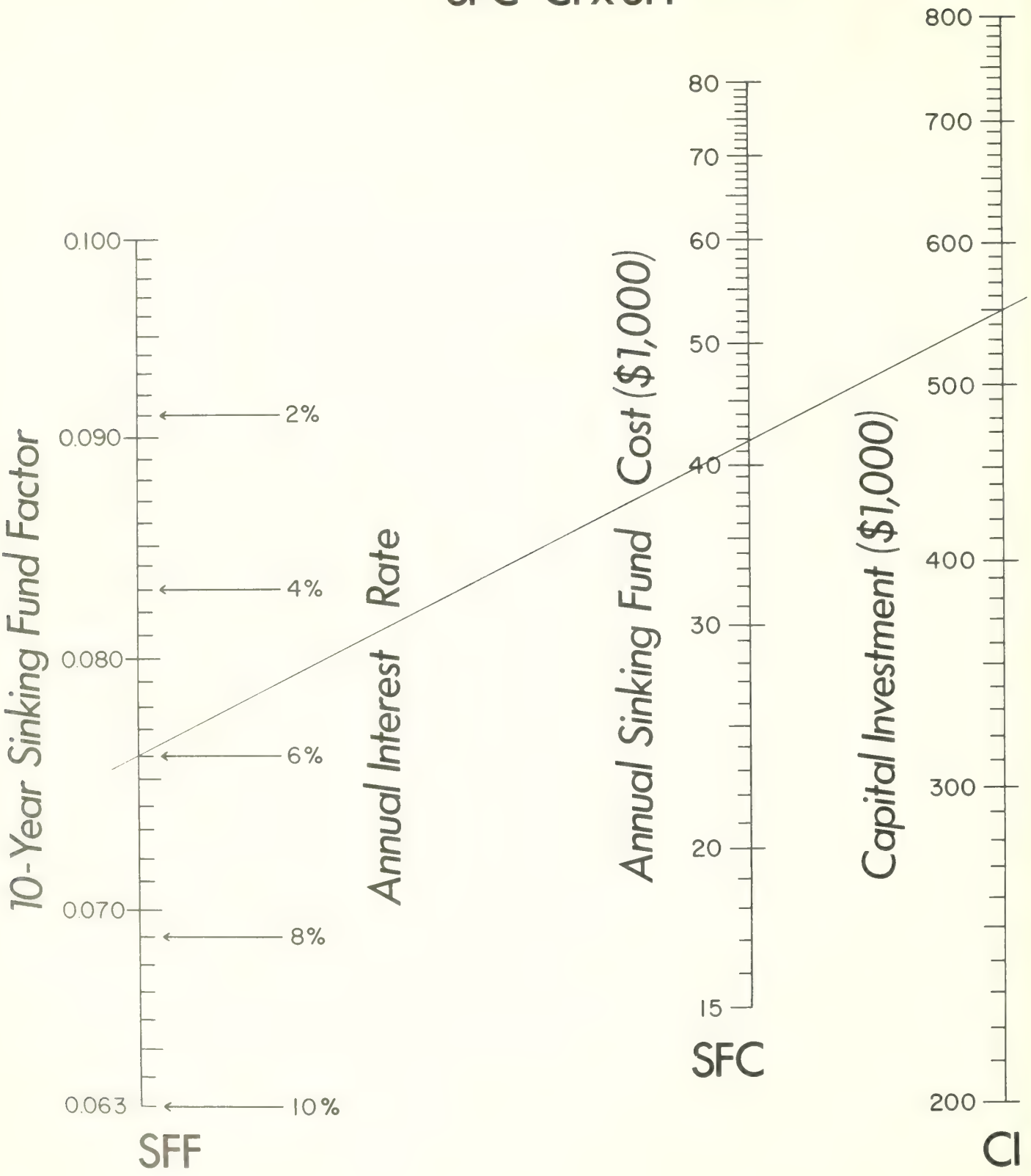
3. Proceed to step 16.

Example:

Taxable income:	$43,000
Tax cost is read as:	14,300

Annual Sinking Fund Cost

SFC = CI x SFF



STEP 16.
SINKING FUND COSTS

Assumption: Ten-year plant life, with no salvage value at the end of that time.

Procedure:

The sinking fund accumulates money to pay off the borrowed capital and the owner's equity investment at the end of the life of the plant. The sinking fund, which is a form of savings, earns interest, which is used to reduce the annual principal payment into the fund.

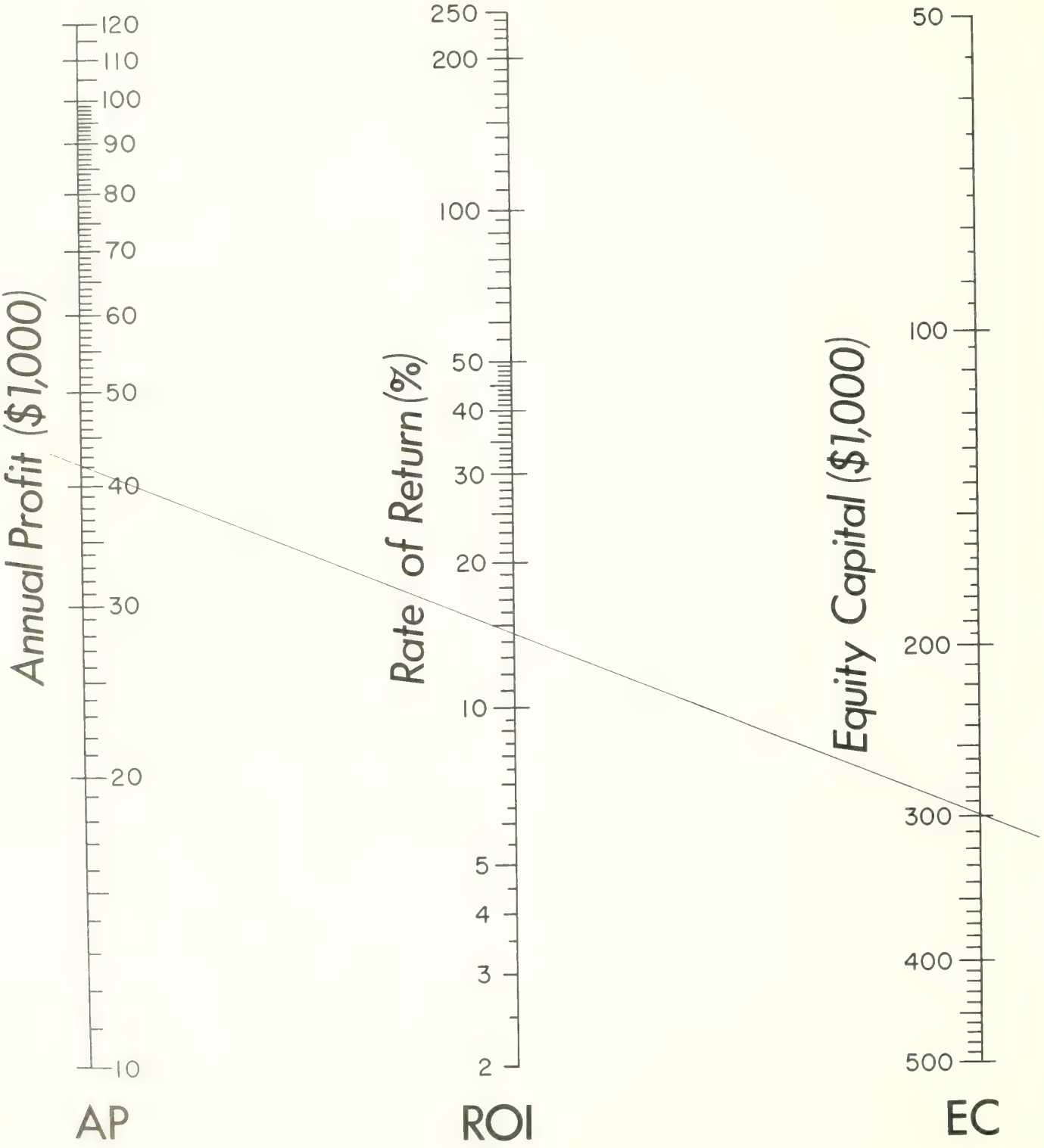
1. Using chart 13, enter the sinking-fund factor corresponding to the sinking-fund annual interest rate on the SFF scale. Enter the total capital investment (item 15) on the CI scale. Read the sinking-fund cost from the SFC scale and enter this value as item 36 on the worksheet.
2. Proceed to step 17.

Example:

Sinking-fund annual interest rate is:	6%
Therefore the 10-year sinking-fund factor is:	0.076
The total capital investment is:	$550,000
The sinking-fund cost is read as:	42,000

Rate of Return on Equity Capital

$$ROI = \frac{AP}{EC} \times 100$$



STEP 17.
DETERMINING THE RATE OF RETURN ON INVESTMENT

Assumption: None.

Procedure:

The return on investment (in percent) is the ratio of the annual profit to the equity capital investment times 100.

1. Determine the total expenses by adding item 31 (expense subtotal), item 35 (tax costs), and item 36 (sinking fund costs). Enter this sum as the expense total (item 37).
2. Determine the annual profit by subtracting item 37 (expense total) from item 25 (total annual income). Enter the annual profit as item 38.
3. Using chart 14, enter the annual profit (item 38) on the AP scale. Enter the equity capital (item 16) on the EC scale. Read the rate of return on investment from the ROI scale.

Example:

Total expenses:	$593,000
Annual profit (annual income — total expenses = $635,000 — $593,000):	42,000
Equity capital:	300,000
Rate of return on equity capital is read as:	14.5%

INFLUENCE OF FACTOR VALUES ON THE RETURN ON INVESTMENT

We have illustrated our method for determining the return on investment for *one* SHOLO mill design and for *one* set of production and financial factors. This method is flexible and can be used for *any* SHOLO mill design and for *any* combination of production and financial factors. Further, the careful user will soon gain an appreciation of the factors most important to him. For any given set of conditions, some factors are more important than others.

Consider some value changes in the factors. Except as otherwise noted, the values of the production and financial factors will remain the same.

EXAMPLE 1.—REDUCE EQUITY CAPITAL TO $275,000 (A $25,000 DECREASE).

Reducing the equity capital to $275,000 will result in a return on investment of about 15.1 percent (up 0.6 percent). At first glance, a larger increase would be expected as we divide the annual profit by the equity capital to arrive at the return on investment. However, there are other effects that must be considered.

Reducing the equity means that more money must be borrowed. In this example, borrowing $25,000 more increases the annual bond interest costs by $2,000, reduces the taxable income by $2,000, reduces the annual tax costs by $1,000, and also reduces the annual profit by $1,000.

Even though the return on investment is not increased greatly, the fact remains that a reduction in equity capital does give a slight improvement. This suggests that an investor should use the minimum equity allowable.

EXAMPLE 2.—INCREASE DAILY INPUT OF LONG LOGS TO 210 TONS (A 10 TON INCREASE).

Increasing the amount of long logs processed per day to 210 tons increases the total annual income by $27,000. (To work this example, start with chart 3. Work backwards to chart 1. Proceed with chart 4 as before.) But the return on investment is increased to only 15 percent (up 0.5 percent). This small increase is the result of the following changes:

Factor	*Amount of increase*
Pallet parts	0.7MBF/day
Pulp chips	5 tons/day
Income from sale of pallet parts	$20,000/year
Income from sale of pulp chips	$ 7,000/year
Long-log costs	$17,000
Operating costs	$ 6,000
Tax costs	$ 2,000
Annual profit	$ 2,000

Though income is increased by $27,000, costs are increased by $25,000. So the increase in profits is only $2,000 per year.

If we conclude that there is no need to increase the operating costs, then we still do not change the result appreciably. By not increasing these costs by $6,000, we increase the tax costs by $3,000. The net effect is to increase the annual profit by $5,000 rather than the $2,000 mentioned above. The result is that the return on investment is increased to 16.3 percent (up less than 2 percent).

EXAMPLE 3.—INCREASE THE SELLING PRICE OF FINISHED PALLET PARTS TO $135/MBF (AN INCREASE OF $7/MBF).

Increasing the selling price of pallet parts to $135/MBF increases the total annual income by about $27,000. However, the annual profit is increased by only $10,000. This is because the operating costs are increased by $7,000 and the tax costs are increased by $10,000. The net effect is to increase the return on investment to 18 percent (up 3.5 percent).

If we decide not to increase the operating costs by $7,000, then the return on investment will be increased to 18.7 percent (up 4.2 percent). Again, the increase in tax costs (up $13,000) minimizes an increase in profits (up $14,000). A decision must be made whether a 0.7-percent increase in return on investment is worth a $7,000 margin in operating costs.

EXAMPLE 4.—DECREASE THE PROCESSING CREW TO 18 MEN AT $2.50 PER HOUR AND 3 MEN AT $3.50 PER HOUR (A DECREASE OF 2 MEN AT $2.50 PER HOUR).

Operating the mill with two less men at a wage rate of $2.50 increases the return on investment to 16.5 percent (up 2 percent). There is a reduction in annual payroll costs of $11,000 and an increase in tax costs of $5,000. The net effect is an increase in profits of $6,000.

Care must be taken to consider all the desired changes at one time. Adding the increases in the return on investment from each of the four examples (0.6 + 0.5 + 3.5 + 2.0) results in a total increase of 6.6 percent. But, if we make all of the changes at one time, we get a return on investment of 22.5 percent or an increase of 8 percent.

The difference is the result of the arithmetic involved. For example: changing the price and the amount of pallet parts gives slightly more income than adding the increases from (1) increasing the price of the original amount of pallet parts and (2) increasing the amount of pallet parts at the original price. But for the four examples given, there is a more important factor. When done individually, the returns on investment for three of the examples are based on an equity capital of $300,000. Only one example is based on an equity of $275,000. But when all the examples are combined, the effect of all the factors is based on the $275,000 equity.

Individual examples are of value in pointing out important factors. They prevent us from considering only changes in income and require us to consider the affect of changes on profits. From the examples given above, we can see that a reduction in equity

capital or the ability to process 10 tons of long logs more per day will not greatly change the return on investment. On the other hand, increases in the selling price or reductions in labor costs have greater effects.

MODIFYING THE SHOLO MILL DESIGN

The modifications given above are on our SHOLO mill design and on our choice of factors. Though we believe these to be realistic, it is unlikely that most readers will have the same set of conditions. We would like to illustrate the flexibility of the SHOLO-mill concept with an example in which the design of the SHOLO mill is changed.

Assume that 250 tons of long-logs—rather than 200 tons—are available per day. Two questions arise immediately.

First, can we process an additional 50 tons per day with the present design? The answer is no. The capacity of the headrig and the two pairs of tandem straight-line ripsaws are not adequate to handle this amount.

Second, should we convert the extra 50 tons directly to pulp chips? This question requires a deeper analysis. Though there is an adequate chipping capacity, a faster debarker is needed to process the additional 50 tons of long logs during a single shift. An additional $20,000 capital investment will be needed for the improved debarker. An increase of $3,000 per year in operating expenses is required for additional electrical power and maintenance. However, the net income from pulp chips is only about $1,000 per year. Though there is an additional annual income from the sale of pulp chips of $68,000, there is also an additional increase in the annual long-log cost of $67,000. Thus we see that this approach to the conversion of the 50 extra tons of long logs will lose money so we reject it.

There is a third possibility. Having an additional 50 tons of long logs allows the slasher-saw operator to be more selective in bucking the long logs into SHOLO logs. Assume that by

selecting the best 80 percent of the long logs it is reasonable to expect that the long-log potential will increase from 57 to 65 percent. We now have 200 tons of long logs with a long-log potential of 65 percent and 50 tons of long logs for direct conversion into pulp chips. The slasher-saw operator can easily buck the pulp-chip logs into easily handled lengths. Work through this problem step by step and refer to worksheet 2. The following factors are known at the beginning:

Item No.	*Depreciation*	*Amount*
2	Pallet-part selling price	$128/MBF
3	SHOLO-log potential	28%
5	Long-log potential for 200 tons	65%
	Long-log potential for 50 tons	0%
6	Long-log tonnage	250 tons
11	Pulp-chip selling price	$7/ton
12	Weight scaling factor	5,850 lbs/cord
13	Long-log cost per ton	$5.80
16	Equity capital	$300,000
18	Interest rate on borrowed capital and land	8%
19	Interest rate on sinking fund	6%
21	Depreciation schedule	Straight line

To determine the return on investment, we proceed with the following steps:

Step 1.—Determine the SHOLO-log tonnage from 200 tons of long logs at a long-log potential of 65 percent. Using chart 3, we find the SHOLO-log tonnage is 130 tons per day.

Step 2.—Determine the daily pallet part production rate. Using chart 2, we find the pallet-part production rate is 18.2 MBF per day. This amount of parts exceeds the capacity of the two pairs of tandem-operated straight-line ripsaws. We note that an additional pair will be needed, at a cost of $20,000. Also, an additional man, at $2.50 per hour, will be needed to operate the saws.

Step 3.—Determine the annual income from the sale of pallet parts. Using chart 1, we determine the annual income from the sale of pallet parts to be $525,000 per year.

Step 4.—Determine the round-residue quantity. The round-residue quantity is normally determined by subtracting the

SHOLO-log tonnage from the long-log tonnage. In this case, be careful to subtract the SHOLO-log tonnage from the 200 tons of long logs from which they were bucked. Then add the 50 tons of long logs that were not converted to SHOLO logs. In this example we have 120 tons of round residue.

Step 5.—Determine the total daily pulp-chip production. Using charts 4 and 5, we find that the daily pulp-chip production from round residue and from SHOLO-log residue to be 103 and 42 tons respectively. The total pulp-chip production is 145 tons per day.

Step 6.—Determine the annual income from the sale of pulp chips. Using chart 6, we find that the annual income from the sale of the pulp chips is $230,000.

Step 7.—Determine total annual income. Add items 22 and 23 in worksheet 2 to get a total annual income of $755,000.

Step 8.—Determine long-log costs. Using chart 8, we find that the annual long-log cost is $330,000.

Step 9.—Determine labor costs. In step 2, we found that an additional man at $2.50 per hour will be needed. Using chart 9, we find that the total annual payroll costs for 21 men at $2.50 per hour and 3 men at $3.50 per hour is $130,000.

Step 10.—Determine financial variables. We estimate that the capital investment will be increased by $50,000 to $600,000 and that this additional $50,000 will be borrowed. The $50,000 will be used to improve the debarking capacity and for an additional pair of straight-line ripsaws. This sum is adequate to cover any capital improvements required by these two items.

An additional $8,000 in operating money is needed to cover the additional costs of the extra man and the additional electrical power and maintenance. Because the total annual income has been increased, we can supply the additional money with a factor of 18 percent of this income reserved for operations.

Step 11.—Determine annual interest charges. The land interest costs remain the same at $1,600. But the borrowed capital has

been increased by $50,000 to $300,000. Using chart 11, we find the borrowed capital interest to be $24,000 per year.

Step 12.—Determine annual depreciation. The total capital investment has been increased by $50,000 to $600,000. Using a 10-year plant life and straight-line depreciation, we find that the annual depreciation is $60,000 per year.

Step 13.—Determine tax costs. The total annual income is $755,000. The total cost for tax purposes is $681,000. Therefore the taxable income is $74,000. Using chart 12, we find the tax costs to be $29,100.

Step 14.—Determine annual sinking-fund costs. Using chart 6, we find that the sinking-fund cost for $600,000 at an annual interest rate of 6 percent is $45,200 per year.

Step 15.—Determine the return on investment. The total annual expenses for the SHOLO mill are found to be $695,000. When this amount is subtracted from the total annual income of $755,000, the result is an annual profit of $60,000. Using chart 14, we find that the return on investment is 20 percent.

Conclusion:—Modifying the SHOLO mill design in the manner described is worthwhile.

SUMMARY

One way to decide whether to invest in a SHOLO mill is to determine the return on invested capital and compare this with other alternatives. This report is a working tool in which is given a detailed procedure for determining the return on investment. Basing examples on actual pilot-plant tests of samples of raw material, we have illustrated the influence of individual factors. The flexibility of the procedure is shown by making several changes in the design of the SHOLO mill. Without attempting to show the best set of conditions, we have illustrated how different returns on investment, from 14 to 22.5 percent, are obtainable when converting low-grade hardwood logs to pallet parts and pulp chips.

Item	Description		Amount
	PRODUCTION VARIABLES		
1	Pallet part production rate	(MBF/Day)	16
2	Pallet part selling price	($/MBF)	128
3	SHOLO log potential	(%)	28
4	SHOLO log tonnage	(Tons/Day)	114
5	Long log potential	(%)	57
6	Long log tonnage	(Tons/Day)	200
7	Round residue quantity (Item 6 less 4)	(Tons/Day)	86
8	Pulp chips from round residue	(Tons/Day)	74
9	Pulp chips from SHOLO logs	(Tons/Day)	37
10	Total daily pulp chip production (Item 8 plus 9)	(Tons/Day)	111
11	Pulp chip selling price	($/Ton)	7
12	Weight scaling factor	(Lbs/Cord)	5,850
13	Long log cost per ton	($/Ton)	5.80
	LABOR VARIABLES		
14	No. of employees and wage rate	($/Hour)	20@2.50
		($/Hour)	3@3.50
		($/Hour)	
	FINANCIAL VARIABLES		
15	Capital investment (total)		550,000
16	Equity capital		300,000
17	Borrowed capital		250,000
18	Interest rate on borrowed capital and land	(%)	8
19	Interest rate on sinking fund	(%)	6
20	Percentage of total income reserved for operations	(%)	20
21	Depreciation schedule		Straight line

Item	Description	Amount (thousands)
	ANNUAL INCOME	
22	Sale of pallet parts	760
23	Sale of pulp chips	175
24	Additional sales	0
25	Total annual income	935
	ANNUAL EXPENSES	
26	Long log costs	263
27	Payroll costs	2[illegible]
28	Operating costs	2[illegible]
29	Land interest costs	[illegible]0
30	Bond interest costs	[illegible]0
31	Expense subtotal	530.6
32	Annual depreciation	55
33	Total cost for tax purposes (Items 31+32)	592
34	Taxable income (Item 25 less 33)	43
35	Tax costs	14.3
36	Sinking fund costs	4.2
37	Expense total (Sum of 31+35+36)	549
	ANNUAL PROFIT	
38	Profit (Item 25 less 37)	42
39	Return on investment = Annual profit / Capital investment x 100	14.5

USDA Forest Service
Northeastern Forest Experiment Station
Forest Products Marketing Laboratory
Princeton, West Virginia

by Hugh W. Reynolds and Charles J. Gatchell

SHOLO ROI TRIAL NO. _____

Location/Description _____

Prepared by: _____

Title: _____ Date _____

Reviewed by: _____

Title: _____ Date _____

Item	Description		Amount
	PRODUCTION VARIABLES		
1	Pallet part production rate	(MBF Day)	18.2
2	Pallet part selling price	($/MBF)	128
3	SHOLO log potential	(%)	28
4	SHOLO log tonnage	(Tons/Day)	30
5	Long log potential	(%)	65
6	Long log tonnage	(Tons/Day)	200+50
7	Round residue quantity (Item 6 less 4)	(Tons/Day)	70 + 50
8	Pulp chips from round residue	(Tons/Day)	103
9	Pulp chips from mill [illegible]	(Tons/Day)	42
10	Total daily pulp chip production (Item 8 plus 9)	(Tons/Day)	145
11	Pulp chip selling price	($/Ton)	7
12	Weight scaling factor	(Lbs/Cu Ft)	5,850
13	Long log cost per ton	($/Ton)	5.80
	LABOR VARIABLES		
14	No. of employees and wage rate	($/Hr)	21@2.50
		($/Hr)	3@3.50
		($/Hr)	
	FINANCIAL VARIABLES		
15	Capital investment (total)		600,000
16	Equity capital		300,000
17	Borrowed capital		300,000
18	Interest rate on borrowed capital and land	(%)	5
19	Interest rate on sinking fund	(%)	6
20	Percentage of total income reserved for operations	(%)	18
21	Depreciation schedule		Straight line

Item	Description	($ thousands)
	ANNUAL INCOME	
22	Sale of pallet parts	525
23	Sale of pulp chips	230
24	Additional sales	
25	Total annual income	55
	ANNUAL EXPENSE	
26	Long log costs	330
27	Payroll costs	130
28	Operating costs	35
29	Land interest costs	1.0
	Bond interest costs	24
	Expense subtotal	206
	Annual depreciation	60
31	Total cost for tax purposes (Items 31+32)	265
34	Taxable income (Item 25 less 31)	74
35	Tax costs	29.
36	Sinking fund costs	46.2
37	Expense total (Sum of 31+35+36)	395
	ANNUAL PROFIT	
38	Profit (Item 25 less 37)	60
39	Return on investment - $\frac{\text{Annual profit}}{\text{Equity capital}}$	20

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SHOLO TRIAL NO. _____

Location/Description _____

Prepared by: _____

Title: _____ Date _____

Reviewed by: _____

Title: _____ Date _____

Item	Description		Amount
	PRODUCTION VARIABLES		
1	Pallet part production rate	(MBF/Day)	
2	Pallet part selling price	($/MBF)	
3	SHOLO log potential	(%)	
4	SHOLO log tonnage	(Tons/Day)	
5	Long log potential	(%)	
6	Long log tonnage	(Tons/Day)	
7	Round residue quantity (Item 6 less 4)	(Tons/Day)	
8	Pulp chips from round residue	(Tons/Day)	
9	Pulp chips from SHOLO logs	(Tons/Day)	
10	Total daily pulp chip production (Item 8 plus 9)	(Tons/Day)	
11	Pulp chip selling price	($/Ton)	
12	Weight scaling factor	(Lbs/Cord)	
13	Long log cost per ton	($/Ton)	
	LABOR VARIABLES		
14	No. of employees and wage rate	($/Hour)	
		($/Hour)	
		($/Hour)	
	FINANCIAL VARIABLES		
15	Capital investment (total)		
16	Equity capital		
17	Borrowed capital		
18	Interest rate on borrowed capital and land	(%)	
19	Interest rate on sinking fund	(%)	
20	Percentage of total income reserved for operations	(%)	
21	Depreciation schedule		

Item	Description	Amount (thousands)
	ANNUAL INCOME	
22	Sale of pallet parts	
23	Sale of pulp chips	
24	Additional sales	
25	Total annual income	
	ANNUAL EXPENSES	
26	Long log costs	
27	Payroll costs	
28	Operating costs	
29	Land interest costs	
30	Bond interest costs	
31	Expense subtotal	
32	Annual depreciation	
33	Total cost for tax purposes (Items 31+32)	
34	Taxable income (Item 25 less 33)	
35	Tax costs	
36	Sinking fund costs	
37	Expense total (Sum of 31+35+36)	
	ANNUAL PROFIT	
38	Profit (Item 25 less 37)	
39	Return on investment = $\frac{\text{Annual profit}}{\text{Equity capital}} \times 1$	

USDA Forest Service
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SHOLO ROI TRIAL NO. _____

Location/description _____

Prepared by: _____

Title: _____ Date _____

Reviewed by: _____

Title: _____ Date _____

Item	Description	Amount
	PRODUCTION VARIABLES	
1	Pallet part production rate (MBF/Day)	
2	Pallet part selling price ($ MBF)	
3	SHOLO log potential (%)	
4	SHOLO log tonnage (Tons/Day)	
5	Long log potential (%)	
6	Long log tonnage (Tons/Day)	
7	Round residue quantity (Item 6 less 4) (Tons/Day)	
8	Pulp chips from round residue (Tons/Day)	
9	Pulp chips from SHOLO logs (Tons/Day)	
10	Total daily pulp chip production (Item 8 plus 9) (Tons/Day)	
11	Pulp chip selling price ($/Ton)	
12	Weight scaling factor (Lbs/Cord)	
13	Long log cost per ton ($/Ton)	
	LABOR VARIABLES	
14	No. of employees and wage rate ($/Hour)	
	($/Hour)	
	($/Hour)	
	FINANCIAL VARIABLES	
15	Capital investment (total)	
16	Equity capital	
17	Borrowed capital	
18	Interest rate on borrowed capital and land (%)	
19	Interest rate on sinking fund (%)	
20	Percentage of total income reserved for operations (%)	
21	Depreciation schedule	

Item	Description	Amount (thousands)
	ANNUAL INCOME	
22	Sale of pallet parts	
23	Sale of pulp chips	
24	Additional sales	
25	Total annual income	
	ANNUAL EXPENSES	
26	Long log costs	
27	Payroll costs	
28	Operating costs	
29	Land interest costs	
30	Bond interest costs	
31	Expense subtotal	
32	Annual depreciation	
33	Total cost for tax purposes (Items 31+32)	
34	Taxable income (Item 25 less 33)	
35	Tax costs	
36	Sinking fund costs	
37	Expense total (Sum of 31+35+36)	
	ANNUAL PROFIT	
38	Profit (Item 25 less 37)	
39	Return on investment = $\frac{\text{Annual profit}}{\text{Equity capital}} \times 100$	

USDA Forest Service
Northeastern Forest Experiment Station
Forest Products Marketing Laboratory
Princeton, West Virginia

by Hugh W. Reynolds and Charles J. Gatchell

SHOLO ROI TRIAL NO. _____

Location/description _____

Prepared by: _____

Title: _____ Date _____

Reviewed by: _____

Title: _____ Date _____

Item	Description	Amount
	PRODUCTION VARIABLES	
1	Pallet part production rate (MBF/Day)	
2	Pallet part selling price ($/MBF)	
3	SHOLO log potential (%)	
4	SHOLO log tonnage (Tons/Day)	
5	Long log potential (%)	
6	Long log tonnage (Tons/Day)	
7	Round residue quantity (Item 4 less 4) (Tons/Day)	
8	Pulp chips from round residue (Tons/Day)	
9	Pulp chips from SHOLO logs (Tons/Day)	
10	Total daily pulp chip production (Item 8 plus 9) (Tons/Day)	
11	Pulp chip selling price ($/Ton)	
12	Weight scaling factor (Lbs/Cord)	
13	Long log cost per ton ($/Ton)	
	LABOR VARIABLES	
14	No. of employees and wage rate ($/Hour)	
	($/Hour)	
	($/Hour)	
	FINANCIAL VARIABLES	
15	Capital investment (total)	
16	Equity capital	
17	Borrowed capital	
18	Interest rate on borrowed capital and land (%)	
19	Interest rate on sinking fund (%)	
20	Percentage of total income reserved for operations (%)	
21	Depreciation schedule	

Item	Description	Amount (thousands)
	ANNUAL INCOME	
22	Sale of pallet parts	
23	Sale of pulp chips	
24	Additional sales	
25	Total annual income	
	ANNUAL EXPENSES	
26	Long log costs	
27	Payroll costs	
28	Operating costs	
29	Land interest costs	
30	Bond interest costs	
31	Expense subtotal	
32	Annual depreciation	
33	Total cost for tax purposes (Items 31+32)	
34	Taxable income (Item 25 less 33)	
35	Tax costs	
36	Sinking fund costs	
37	Expense total (Sum of 31+35+36)	
	ANNUAL PROFIT	
38	Profit (Item 25 less 37)	
39	Return on investment = $\frac{\text{Annual profit}}{\text{Equity capital}} \times 1$	

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CONVERTING HARDWOODS

on poor sites

TO WHITE PINE

by planting and direct seeding

by G. W. Wendel

U.S.D.A. FOREST SERVICE RESEARCH PAPER NE-188
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NORTHEASTERN FOREST EXPERIMENT STATION, UPPER DARBY, PA.
FOREST SERVICE, U. S. DEPARTMENT OF AGRICULTURE

The Author

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COVER PHOTO—*A typical stand of hardwoods growing on a poor site in West Virginia.*

CONVERTING HARDWOODS on poor sites TO WHITE PINE by planting and direct seeding

Increased Returns From Poor Sites

UNTIL RECENTLY, conversion of hardwood stands on poor sites to white pine (*Pinus strobus* L.) was limited mostly to natural white pine reproduction released from a hardwood overstory, either by killing the hardwoods or by removing them through a timber sale. However, in our effort to increase the returns from poor sites in West Virginia (oak site index 45 to 60) we have been introducing white pine where advanced natural white pine is scarce or absent. The results of several conversion studies completed during the past 6 years and the results of pertinent research conducted elsewhere are summarized and reported here.

Background

Research results give substantial evidence that, within the range of site quality we are working with, white pine grows considerably faster and will yield a higher return than the hardwoods. Doolittle *(1958)* found that, in the southern Appalachians, site index 52 for northern red oak (*Quercus rubra* L.)—47 for white oak (*Quercus alba* L.)—is site index 60 for white pine. In terms of volume production, the projected yield for oak stands on site index 57 was about 5.4 M board feet per acre, compared to 24.0 M board feet per acre for white pine.

We know much about natural white pine reproduction and growth that can be applied to sites where white pine must be introduced by planting or seeding. In its early years, white pine is tolerant of light to medium overstory shade. Although optimum growth is not achieved under these conditions, natural seedlings that survive leaf smothering and other hazards the first few years continue to survive and grow slowly in height as long as they receive 20 percent or more of full sunlight *(USDA 1965)*. However, for optimum growth, established white pines grow best under conditions of greater sunlight.

A recently completed study showed that height growth of white pine seedlings grown 3 years in pots was not appreciably greater under full sunlight than under 55-percent shade (table 1). However, height growth was much less under 80-percent shade, indicating that the point where shade began to seriously affect height growth of seedlings was somewhere between 55 and 80 percent (fig. 1).

Table 1.—*Average total height of white pine seedlings at the end of three growing seasons under four intensities of shade*

Treatment	Percent shade			
	0	55	80	90
	In.	*In.*	*In.*	*In.*
Not released	8.1	8.9	6.4	4.3
Released[1]	—	8.5	6.9	4.4

[1]Seedlings moved to full sunlight at the end of 2 growing seasons and grown in full sunlight for an additional year.

Figure 1.—Total height of white pine seedlings grown in pots under 0, 55, 80, and 92 percent shade, after 3 years.

Three-year-survival averaged 85 percent under 0-, 55-, and 80-percent shade and dropped to 47 percent under 92-percent shade.

Lane *(1959)* concluded from a summary of previous research on release of naturally established white pine under hardwoods that:

- Height of the pines at the time of release was important if the pines were to compete successfully with a regrowth of hardwoods. For example, in the Lake States, white pines 8 feet tall competed successfully with aspen (*Populus* sp.) regrowth, and pines 6 feet tall kept ahead of regrowth of vegetation in cutover oak stands. In New England, the optimum release height for pines was 15 feet when they were dominated by aspen and 12 feet when they were dominated by red maple (*Acer rubrum* L.) (However, our observations in West Virginia indicated that, on most of our conversion sites, white pines more than 3 feet tall compete successfully with the growth of the sprouts and other vegetation after the overstory is cut).
- Intensity of competition is usually greater on the better sites than on the poorer sites. In general, this is considered to be

due largely to the greater abundance and more rapid growth of competing vegetation on the better sites.

- In order of competing ability, gray and paper birch (*Betula alleghaniensis* Britton and *B. papyrifera* Marsh.) are weak competitors, aspen and oaks are intermediate, and red maple is a strong competitor to white pine.

Conversion with Artificial Reproduction

Until a few years ago, conversion to white pine by artificial methods in West Virginia was tried mostly in small underplantings or plantings on cutover areas. The results of underplanting studies showed that, on areas of low site quality, introduced pines survived well under hardwood overstories. The results were not so good on cutover areas, where dense clumps of hardwood sprouts and other vegetation soon provided heavy shade that proved detrimental to pine survival and growth. These effects were more pronounced on the better sites.

The greatest drawback to planting is cost. In the mountains of West Virginia, it has been costing $50 to $60 to plant about 700 trees per acre. To get away from high planting costs, emphasis was shifted to direct-seeding. The shift was encouraged by the development of bird and rodent repellents for seeds and by the successes in direct-seeding the southern pines *(Mann 1965)*.

UNDERPLANTING

Probably the oldest documented white pine underplanting study in West Virginia was begun in 1954 on a typical conversion area on Clover Run near Parsons. The seedlings (3-0 stock) were underplanted at a spacing of about 9 feet beneath a 50-year-old oak stand on a southwest slope. Six plots were laid out on three site strata; the lower-slope plots had an oak site index of 59 *(Schnur 1937)*; middle slope, 53; and upper slope, 45. On one of the site-paired plots, the overstory was untreated; on the other, the overstory was girdled immediately after planting.

After four growing seasons, the treated plots were split, and the pines on half of each were given a second release *(Yawney 1961)*. After 15 growing seasons (in 1968), the plots were remeasured and the results were tabulated.

Survival ranged from 80 to 96 percent and averaged 90 percent for all plots (table 2). Only on the released plots on the best site did survival appreciably differ from the average: there it was lower. This can probably be attributed to a greater surge of competing vegetation after release.

Total height of the unreleased pines on the two poorest sites averaged 2 feet taller than the unreleased pines on the best site (table 3, fig. 2), probably because the overstory was denser on the better site.

Released pines on the upper-slope plot (poorest site) were taller than their counterparts on the middle and lower slopes (table 3, fig. 2). After 15 years, this difference was about 5

Table 2.—*Survival of underplanted white pine after 15 growing seasons*

Oak site index	No release	Released[1]
	Pct.	*Pct.*
59	88.2	80.5
52	91.1	96.1
45	90.5	93.6
Average	89.9	90.1

[1]Averaged for once- and twice-released areas combined.

Table 3.—*Average total height and d.b.h. of underplanted white pine at the end of 15 growing seasons by site index and release treatment*

Plot location	Oak site index	No release		One release		Two releases	
		Height	D.b.h.	Height	D.b.h.	Height	D.b.h.
		Ft.	*In.*	*Ft.*	*In.*	*Ft.*	*In.*
Lower slope	59	4.4	0.17	13.3	1.43	18.1	2.47
Middle slope	52	6.1	.43	11.7	1.17	18.2	2.25
Upper slope	45	6.4	.45	18.8	2.30	19.1	2.49

Figure 2.—Fifteen-year average heights of underplanted white pines: *A*, unreleased pine on poor site, *B*, unreleased pine on best site, *C*, once-released pine on the poorest site, *D*, once-released pine on the best site.

feet for the once-released pines and 1 foot for the twice-released pines.

After 15 years, on the lower-slope and middle-slope plots, appreciably more pines were free to grow or likely to get through on the twice-released areas than on the once-released plots. On the upper slope—the poorest site—two releases showed a much smaller advantage over one release (table 4).

Diameter growth followed the same general relationships with site and release as did height growth (table 3).

We may conclude from this study that on sites similar to the study area:

- Excellent survival of underplanted white pines can be maintained for at least 15 years.
- Without overstory treatment, 3-0 underplanted white pines will average between 4 and 6 feet tall after 15 years.
- After 15 years on areas with an oak site index of about 45, 40 percent of the pines will be free to grow if the overstory is killed at planting time; on areas of oak site index 60, only

Table 4.—*Percentage of underplanted white pines by suppression rating and release treatment at the end of 6 (1954) and 15 (1968) growing seasons*

Year	Oak site index	Suppression rating[1]					
		One release[2]			Two releases		
		A&B	C	D	A&B	C	D
1959	59	12	58	30	42	44	14
1968		20	27	53	50	28	22
1959	52	21	48	31	60	35	5
1968		10	26	64	40	31	29
1959	45	37	46	17	74	19	7
1968		39	19	42	17	29	54

[1] A = Pines free to grow
B = Pines likely to get through
C = Pines likely to be suppressed
D = Pines suppressed

[2] Released at planting time

[3] Released at planting time and at 4 years

half as many pines will be in this favorable position. Two releases on the site of highest quality equalled the effect of one on the poorest.

The release treatments probably were not made at the best time. Planted pines usually require 3 to 5 years before they are well established. Because white pines in juvenile stages are quite tolerant of shade, it might be best to wait 5 to 10 years before release. This viewpoint is supported by results reported by Goebel and Cool *(1968)* in the Upper Piedmont of South Carolina. They reported excellent response of severely suppressed underplanted white pines after 20 years. They said that release response appeared to be related to height of the pines; but after a few years, many of the shorter trees had caught up.

Walters *(1959)* reported good to excellent 5-year survival of white pines planted after clearcutting oak stands in southeastern Ohio. He suggested that on the poorest sites many of the pines keep pace with or outgrow the hardwood sprouts, and thus an early release is probably not justified.

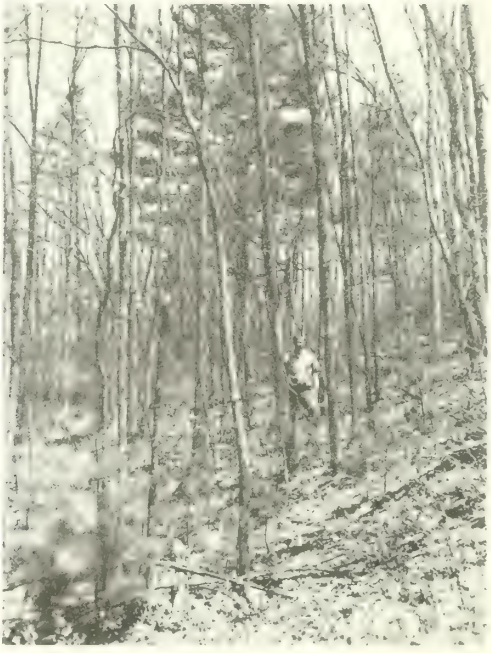

Figure 3.—Typical poor-site-hardwood stand with an understory of advanced natural white pine reproduction.

Table 5.—*Average number of advanced white pine seedlings per acre and percent of milacres stocked before and after logging on four typical conversion areas in West Virginia*

Time	Cut per acre	Height class (inches)					
		0-6	6-12	12-24	24-36	36+	Total
	Cords	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*
Before	11.8	1,378	394	484	228	494	2,978
After	—	846	305	400	189	428	2,168
Percent loss	—	39	23	17	17	13	27

Geerinck and others *(1954)* reported high survival of white pines underplanted in mixed stands in Maine after 18 growing seasons. Best height growth was obtained under a light canopy, which minimized the growth of understory vegetation and allowed the more tolerant white pines to grow satisfactorily.

Clements *(1966)* reported that underplanted white pines, 4 to 6 feet tall, competed successfully with understory vegetation in thinned aspen sucker stands in Canada.

The risk in underplanting is that the seedlings will be destroyed if the overstory is removed by a logging operation. To determine what portion of the seedlings might be destroyed, we determined the losses from clearcutting on four typical conversion areas in West Virginia (fig. 3).

Before cutting, the four areas averaged about 3,000 white pine seedlings per acre in the understory; 27 percent of these were destroyed in logging (table 5). Milacre plot stocking, which averaged 84 percent before cutting, dropped to 71 percent. The greatest losses were in the 0- to 6-inch height class. Though most of the seedlings were destroyed by logging, some mortality was probably caused by damping-off, leaf smothering, and animal depredations.

DIRECT-SEEDING

Direct-seeding of white pines is not new. In fact, early seeding trials with this species date back 50 years or more *(Baldwin 1965; Roe 1963)*. Some of the trials have been successful, but

a consistent level of success with broadcast and spot-seeding methods has not been attained.

Most failures resulted directly or indirectly from:

- Inadequate site preparation.
- Rodent and bird depredation of seed.
- Unfavorable soil moisture and temperature conditions at time of germination and during the critical first year.
- Low viability of seed and subsequent inadequate seeding rate.
- Smothering of first-year seedlings by hardwood leaves.

Broadcast Seeding

It does not appear that broadcast seeding offers much promise in conversion work in rugged mountain country like West Virginia, mainly because of the difficulty of adequately preparing the site. In addition, most conversion sites are on southerly and westerly aspects, which means that seed lying on the surface is subjected to high temperatures and extreme drying. Thus, short periods of drought may be detrimental to seed germination and seedling establishment.

A large-scale trial of aerial seeding in West Virginia in the spring of 1963 failed. An area of 64 acres, consisting of eight 8-acre plots (four clearcut and four uncut), was seeded from a helicopter at an average sowing rate of 9,000 seeds per acre. An intensive survey of seedlings was made at 60 days, 1 year, and 2 years after sowing. After two growing seasons, less than 1 percent of the milacre plots in any treatment had a white pine seedling. Several factors seemed to be responsible for the failure:

- Lack of rainfall during the critical germination period and afterward in the first summer (this was probably the biggest reason for failure).
- Unfavorable seedbed conditions. Even though about 44 percent of the surface on the logged areas was mineral soil or a mixture of mineral soil and humus, a high proportion of this bare surface consisted of severely compacted horse skid trails.
- Two-low seeding rates.

In another local study, seed was broadcast with a hand seeder in a cutover stand and in an uncut stand at the rate of 1¼ pounds per acre. At the end of the first growing season, milacre stocking (based on 100 milacre plots) was only 20 and 24 percent, respectively.

Spot-Seeding

Because of the lack of success with broadcast seeding, efforts were directed to spot-seeding. In appraising the possibilities of this method, several pertinent questions arose:

- When should seeding be done—before or after removal of the overstory?
- How many seed spots are needed to attain a given stocking per acre?
- Does shape of seed spot affect survival of young seedlings when an overstory is present?
- What effect does initial seed size have on survival and height growth of seedlings?
- How does overstory shade affect the height growth of young seedlings?

Several studies were made to answer these questions. One of these was aimed at determining whether the best time to spot-seed was before or after overstory removal.

Though it was obviously easier to seed in an uncut stand, the results of earlier research had shown that, when this was done, hardwood leaves from the overstory trees smothered many newly germinated pine seedlings.

From observations of some spot-seeding done under canopy, it appeared that the configuration of the seed spot was also an important factor: the deeper the scalp, the greater the tendency for leaves to accumulate in the spots and smother newly emerged seedlings. From this observation, it was hypothesized that low mounds might elevate emerging seedlings and thus reduce losses from leaf-smothering.

A study was begun in 1966 to determine the effect of seed-

spot configuration on the emergence, survival, and growth of seedlings. Under a hardwood overstory on a slightly better than average conversion site, 8 to 10 Arasan-Endrin repellent-coated seeds (see appendix I) were sown during the dormant season in shallow concave seed spots (½ to 1 inch deep) and on low mounds of mineral soil (about 2 or 3 inches high). An attempt was made to protect half of the seed spots from smothering by manually removing the leaves from them, but the wind usually blew the leaves back into the shallow holes, and the treatment was ineffective. Few of the mounds ever became covered with leaves.

Seed size was also considered in the study to determine whether larger and heavier seeds produced taller seedlings than small seeds.

Maximum stocking for both mounds and holes occurred about mid-July during the first growing season (81 and 76 percent respectively). Thereafter, to the end of the growing season, mound stocking decreased 4 percent and hole stocking decreased 10 percent (table 6). Overall mortality of seedlings during the first growing season was due mostly to damping-off (38 percent)

Table 6.—*Percent of seed spots containing seedlings*

[Each value is based on 200 spots]

Seedspot shape	Initial seed size[1]	Date				
		9/67	7/68	10/68	4/69	10/69
		Pct.	*Pct.*	*Pct.*	*Pct.*	*Pct.*
Mound	1	84	44	41	17	21
	2	69	43	39	27	28
	3	79	44	41	24	27
Average	—	77	44	40	23	25
Hole	1	60	17	15	10	13
	2	82	39	40	22	26
	3	55	31	23	20	21
Average	—	66	29	26	17	20

[1] 1 = Seedlot run, not graded by size.
2 = Large seed (average weight 23.3 mg.).
3 = Small seed (average weight 17.3 mg.).

and to soil washing away from the roots on mound spots (53 percent).

During the first winter, the number of spots containing one or more seedlings decreased 50 percent in both types of spots. Frost-heaving caused most of the mortality on mounds, smothering by hardwood leaves caused much of it in the holes. The same factors caused additional mortality the second winter. By the end of the third growing season, only 25 percent of the mounds and 20 percent of the holes had one or more seedlings. No statistically significant difference in spot stocking showed up between treatments for any period.

Lack of protection from leaf mulching probably contributed to frost-heaving on mounds. On the other hand, where leaf mulching occurred in the holes, many seedlings smothered. It would seem that level seed spots—those with slightly convex or concave configuration—would be preferable. For best results, these too would need some protection from leaf accumulation.

At the end of three growing seasons, no differences in seedling height could be attributed to seed size.

In contrast to the results of this study of spot-seeding under canopy, a survey of spot-seeded areas where the canopy was removed showed much better results. Surveys were made of 12 clearcut areas that were spot-seeded (hole method) at a spacing of 8 by 8 feet either just before logging or during the first dormant season after logging. Survival tallies made 3 to 5 years after seeding showed that 66 percent of the spots contained one or more living seedlings (table 7). A relatively constant level of success was attained in early establishment of pine in spite of competition from stump sprouts and other vegetation. However, observations indicated that most of the surviving seedlings would require release before they could be considered free to grow (fig. 4).

Table 7.—*Summary of white pine seed-spot trials on clearcut conversion sites on the Monongahela National Forest*

Ranger district	Compartment No.	When seeded	Seedling age	Spots with one or more seedlings	Seedlings per acre[1]
			Yrs.	*Pct.*	*No.*
White Sulphur	A-20	After cut	5	76	517
	A-14	" "	4	68	462
	D-6	" "	4	79	537
	D-9	" "	4	78	530
	A-14	" "	3	55	374
	D-6	" "	3	65	442
	A-20	" "	3	71	483
	D-13	" "	3	55	374
Potomac	#1	" "	3	53	360
	#2	" "	3	44	299
	PR	Before cut[2]	5	77	524
White Sulphur	A-14	Before cut[2]	3	67	456
Average, all areas		—	—	65	447

[1]Based on 680 spots per acre and at least 1 seedling per spot.
[2]Seeded in winter, canopy removed before the end of the ensuing growing season

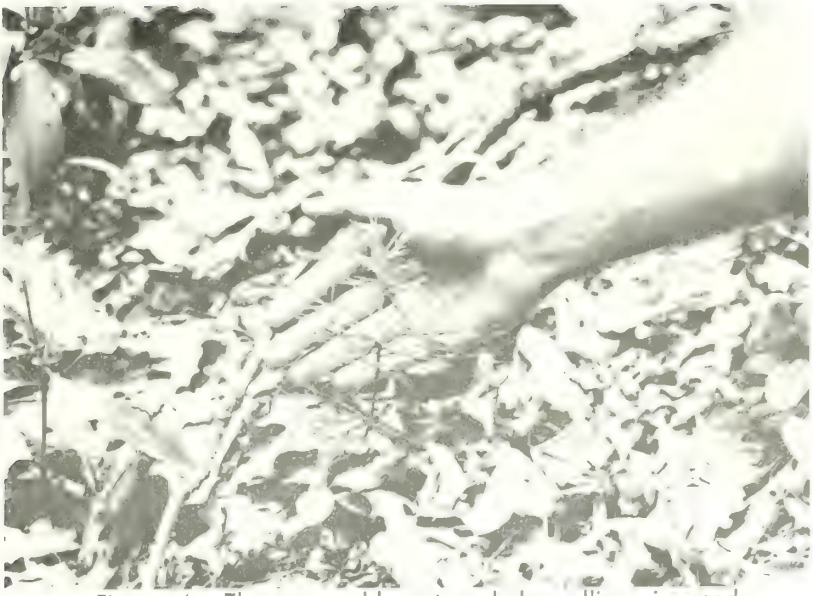

Figure 4.—Three-year-old spot-seeded seedlings in need of release.

Conversion or partial conversion of hardwoods to white pine on poor sites—site index 45 to 60 for oaks—definitely offers an opportunity to increase the value of products grown. Moreover, once the white pine has been successfully established, it can probably be maintained indefinitely as an important constituent of the stand through the use of judicious cutting practices.

The cost of conversion deserves considerable study because this operation comes early in the life of the stand, and interest charges mount up by the time the pine is ready to cut. For example, $10 carried 60 years at 6-percent interest amounts to about $330.

Both planting and direct-seeding have been used to establish white pine in areas of low site quality occupied by hardwoods. Direct-seeding in spots has been most frequently used of late to avoid the high cost of planting and the poor success of broad-

cast seeding. However, recent research results indicate that spot-seeding should be limited to areas without an overstory, because leaf accumulations smother the young pines. And when seeding is done immediately before or after the overstory is removed, the young pines may have to be released twice before many are free to grow. Moreover, the recent ban on hard pesticides has eliminated the use of Endrin as a rodent repellent, which precludes spot-seeding in areas of high rodent populations. Covering untreated seed with a thin layer of soil has prevented serious depredation in New England *(Graber 1969)*, but has not been tested in West Virginia.

Thus a number of considerations are involved in deciding whether to convert or not and, if conversion is favored, what method to use. Research and observations have given us some basis on which to predict chances of success by the different methods. To illustrate, we assumed a goal of 200 established stems per acre 3 years after planting or seeding. We determined the number of planted seedlings or seeded spots necessary to attain this goal by applying survival figures obtained from various studies (table 8).

Considering the results (table 8), we would probably not consider direct-seeding under a canopy. It is unlikely that we would be willing to accept the costs of preparing and sowing 1,370 spots per acre to get 200 established seedlings. The other three methods offer reasonable possibilities, but the data do not show all of the considerations involved.

For example, if we planted recently cutover land, we would need to plant only about 222 trees per acre to have 200 surviving at 3 years. However under these conditions, we would need to make one and possibly two releases to bring a satisfactory number of pines through. In spot-seeding recently cutover land, we would almost surely have to make two follow-up releases. Moreover, with the ban on the use of Endrin as a rodent-repellent seed-coating, direct-seeding would be a risky proposition in West Virginia.

This leaves understory planting. With this method there would be no urgency to release the pines for 5 to 10 years; during this

Table 8.—*Estimated number of seedlings to plant or seed spots to prepare to attain a goal of 200 established white pine seedlings at the end of 3 years*

Item	Planting		Direct-seeding	
	With overstory	Cutover land	With overstory	Cutover land
Expected survival at end of 3 years (percent)	90[1]	90[1]	20	65
Expected loss (percent) in number of seedlings as a result of logging overstory	27[4]		[illegible]	
Approximate initial number of seedlings to plant or spots to prepare	301	222	1,370	308

[1]From table 2, percent of planted seedlings surviving after 3 years.
[2]From table 6, percent of spots with 1 or more seedlings at the end of 3 years.
[3]From table 7, percentage of spots with at least 1 seedling.
[4]From table 5, percent of seedlings destroyed during logging of [illegible] overstory.

period we would not expect mortality to be more than 10 to 15 percent. If the pines were 5 to 10 years old when the overstory was cut, we could expect most of them to develop without further release.

In summary, it seems best to plant 100 to 400 stems per acre (depending on how complete a conversion is desired) under canopy and let them grow for 5 to 10 years before the overstory is removed. Expected mortality would be about 35 percent through the overstory-removal period.

■

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Appendix I

Caution about Pesticides

This publication reports research involving pesticides. It does not contain recommendations for their use, nor does it imply that the uses discussed here have been registered. All uses of pesticides must be registered by appropriate State and/or Federal agencies before they can be recommended.

CAUTION: Pesticides can be injurious to humans, domestic animals, desirable plants, and fish or other wildlife — if they are not handled or applied properly. Use all pesticides selectively and carefully. Follow recommended practices for the disposal of surplus pesticides and pesticide containers.

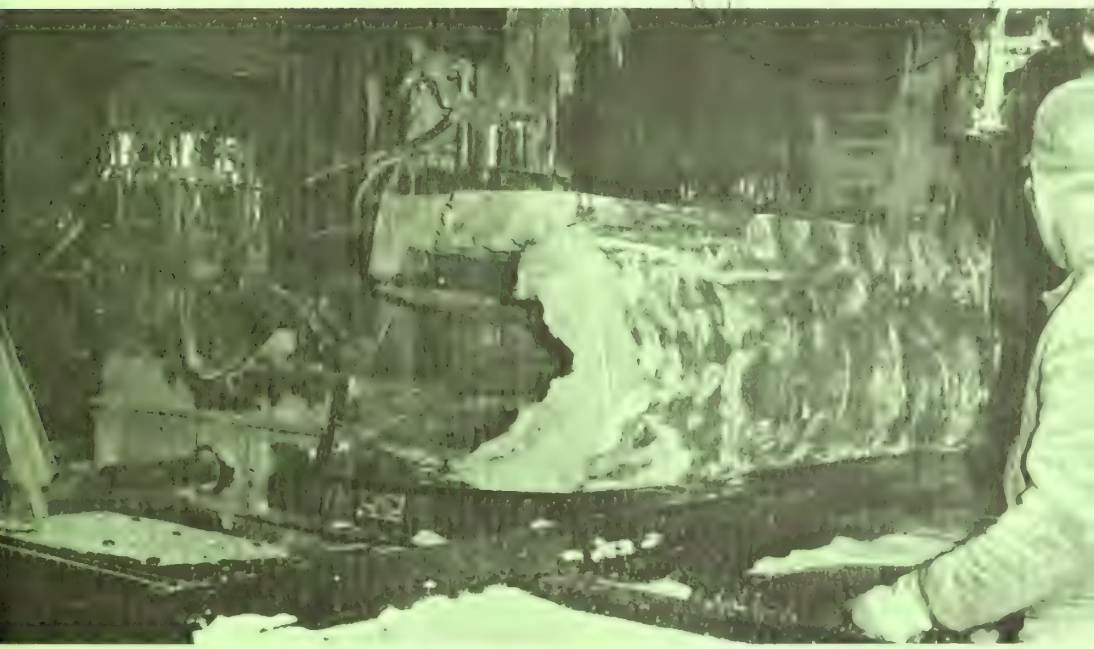
Acknowledgment

The author thanks the timber management staff and district personnel of the Monongahela National Forest for contributions of land, data, and field assistance in carrying out many of the recent white pine conversion studies made in West Virginia.

THE FOREST SERVICE of the U. S. Department of Agriculture is dedicated to the principle of multiple use management of the Nation's forest resources for sustained yields of wood, water, forage, wildlife, and recreation. Through forestry research, cooperation with the States and private forest owners, and management of the National Forests and National Grasslands, it strives — as directed by Congress — to provide increasingly greater service to a growing Nation.

Technical Considerations in Harvesting and Sawing DEFECTIVE HARDWOOD BUTTS

JUL 28 1971



by Thomas W. Church, Jr.

U.S.D.A. FOREST SERVICE RESEARCH PAPER NE-189
1971

NORTHEASTERN FOREST EXPERIMENT STATION, UPPER DARBY, PA.
FOREST SERVICE, U.S. DEPARTMENT OF AGRICULTURE
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HOW IMPORTANT are butt defects in hardwoods? We have no reliable estimate of the volume or value of timber lost through basal injuries. However, butt defects will be almost as important in future timber harvests as they are at present. Why? Because most butt defects are due to two causes: fire and logging. Damage from both these agents may be reduced, but it certainly will not be eliminated.

Fire injury exposes large areas of the tree bole to the harmful effects of diseases that rot heartwood. A recent study in stands of oak saplings, poles, and sawtimber revealed that fire was the major cause of butt injury (*1*). Wildfire may cause even greater injury to other hardwood species. After a wildfire in cove hardwood saplings, investigators found that 41 percent of the desirable dominant stems that were not killed had basal scars or incipient rot (2).

Some residual stems are usually wounded during logging. The frequency and severity of this injury depends upon the cutting practices employed, the residual stand density, and the type of equipment used (*4, 8*). Position and size of the wound often govern the extent of the basal injury that develops as the trees grow. Although techniques have been developed for predicting the amount of internal damage from logging wounds on certain species, a reliable estimate of decay and discoloration from logging wounds on northern hardwoods cannot be made on the basis of external features alone (*8*).

Since the major causes of butt defect may continue to prevail in future decades, the utilization of this unsound timber will continue to challenge hardwood lumbermen. What policy should sawmill operators follow regarding the use of defective butts? Previous research has shown that internally defective butt logs from high-value species like maple and birch can be profitably harvested and sawed (3, 5). So loggers should remove unsound butt portions only (1) when the collar of sound wood surrounding rot or voids is less than 6 inches thick, or (2) when the combination of internal defect and butt flare are extreme. For butts with internal defects plus catfaces, the shell of sound wood must average 6 inches, including the open wound on the scarred face. Otherwise such a combination of butt defects should be bucked off.

If sawmills adopt these recommendations, supervisors should be aware of some of the technical problems they will face. The most important questions are: (1) How will the acceptance of defective logs influence truckload volume and hauling costs? (2) Can scalers accurately estimate the deductions for cull? (3) Are log sawing times substantially increased? (4) How does the value of lumber sawed from defective logs compare with the value of lumber sawed from sound logs?

The following discussions of these questions are based on the analysis of data collected from 219 sugar maple butt logs, 57 percent of which had internal defects. Our objective in presenting this information is not to establish relationships between the amount of internal defect and net sawlog value, but rather to show sawmill operators how their logging and milling practices might be affected if they utilize defective butts.

TRUCKLOAD VOLUME

Suppose sawmill operators decide to saw all but the most defective butts. How will this change in policy affect the business relationships between them and their contract loggers?

Certainly the contractors will realize that they have to deliver more gross volume for the same pay, because payment is based on net scale. Does transporting defective butts actually reduce net truckload volume? If so, contractors and truckers might right-

fully expect to get a higher price per thousand board feet net scale to cover the extra loading and hauling costs.

Anticipating this problem in business relationships, we measured the gross and net volumes on trucks loaded with the type of logs meeting current merchantability standards. Then we compared these values with truckload volumes where at least one log on each load was one of our sample defective butts. A defective butt is defined as a log having an internal defect over 6 inches in diameter that warrants a cull deduction of at least 20 board feet.

These comparisons were based on 53 loads of merchantable logs and 79 loads of both merchantable and defective logs. Twenty-eight percent of the 79 loads of mixed logs had two or more defective butts per load.

Average net volume per load was nearly identical regardless of the condition of the logs hauled. Trucks hauling a mixture of merchantable and defective logs carried about 75 board feet more gross volume per load than trucks hauling merchantable logs only. And cull volume was about 80 board feet higher on loads with defective logs. The differences in average truckload volume—in board feet, Doyle scale—were:

Log volume class	*Merchantable logs*	*Merchantable and defective logs*
Gross	2,280	2,353
Net	2,223	2,214
Cull	57	139

These findings show that mill operators will not need to pay contractors more money for hauling defective logs because there was less than 10 board feet difference in the average net volume hauled. The greater gross volumes associated with loads containing defective logs may be attributed to the larger diameters of the unsound butts. The one or two big defective logs on each load apparently occupied the restricted cargo space more efficiently than the smaller logs normally carried.

Since extra trips would not be needed to haul a given net volume that included defective logs, logging costs should remain unchanged. In fact, logging costs might actually decline slightly. Under current utilization standards, contractors remove butt defects at their own expense rather than incur a scaling penalty.

SCALING ACCURACY

Operators who plan to saw internally defective butts should know whether they can measure net volume accurately. If company scalers cannot correctly deduct for internal cull, the net dollar income from defective logs could vary substantially.

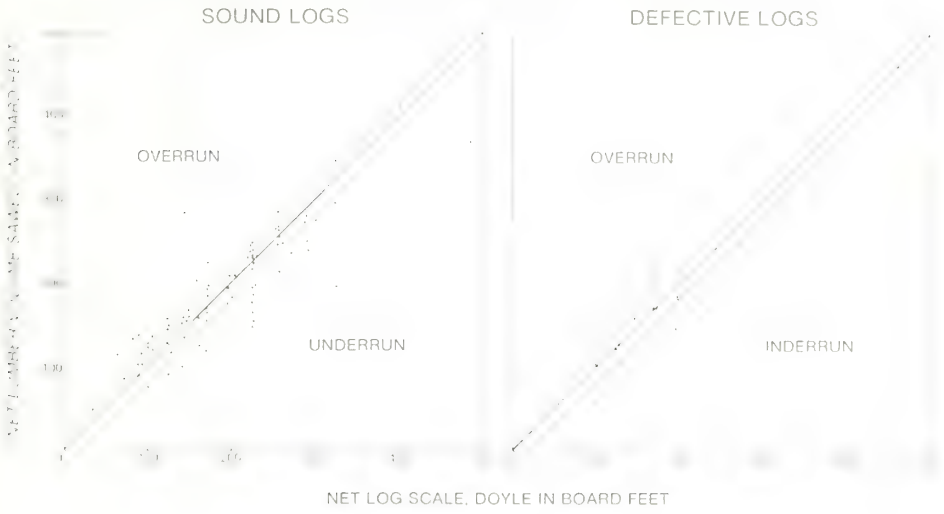
In the Appalachian area, most of the timber sales and contractor payments are based on the Doyle rule. When properly applied, this log rule usually gives a big overrun, especially for logs in the smaller diameter classes. But these underestimates of actual lumber volume are usually worked out in price negotiations. However, scalers using the Doyle rule have no reliable method for making cull deductions. They adjust for cull defects by reducing log diameter or length according to their best judgment of the cull volume. Such unscientific practices could seriously hamper efforts to utilize more of the partially defective timber now wasted.

In this evaluation, we had an excellent opportunity to compare the actual lumber yield with the scaled volume for each of the 219 sample logs used. Although the company scaler had been working with the same mill crew for several years, his estimates of net volume were considerably above and below the lumber yields from individual logs. Differences in overrun and underrun frequently exceeded 25 board feet per log. Occasionally the spread between lumber yield and log scale exceeded 100 board feet per log.

In plotting the overrun and underrun for individual logs, the dispersion for sound logs appeared to be more compact than the scatter for defective logs (fig. 1). This impression proved to be correct, for in evaluating the actual values, we found that the scaler made a poorer volume estimate of the defective logs. In fact, his percentage underrun for defective logs was more than twice that for the sound logs:

	Sound logs (board feet)	*Defective logs (board feet)*
Net scale	18,785	26,442
Overrun	1,040	2,065
Underrun	1,365	3,061
Net underrun	325	996
Percent of underrun	1.7	3.8

Figure 1.—Differences between log scale and lumber yield for sound and defective sugar maple butt logs.



We were surprised to find an underrun. Lumber yields from sound logs of this size should exceed scaled volumes when the Doyle rule is used. Obviously the company scaler made liberal estimates of net volume in both sound and defective logs. Since this timber came from company lands, the only beneficiary of this overestimate was the logging contractor, who was paid on the basis of net scale.

How much was the contractor overpaid? That depends upon what overrun factor the company used in setting the contract price. If they expected neither an overrun nor an underrun, then at $40 per MBF (thousand board feet) log scale, they paid the contractor about $0.70 per MBF too much for sound logs and about $1.50 per MBF too much for defective logs. But if the company expected a 10-percent overrun at the $40 per MBF delivered price, then they overpaid the contractor about $4.25 per MBF for sound logs and about $5.00 per MBF for defective logs. These figures illustrate why the level of scaling accuracy must be known in advance of price negotiations, especially when defective logs will be purchased.

SAWING TIME

Sawmill operators who plan to saw defective butts must face the fact that these logs take longer to saw. The average sawing time for unsound butts below 20 inches in diameter ranged from ½ to 1 minute longer than the average sawing time for sound logs of similar size. In the larger diameters, defective logs took 1 to 1½ minutes longer to saw than sound logs of equivalent size (fig. 2).

The sawyer handled defective logs with greater caution. The feed rate was slower—perhaps to minimize the danger of sudden collapse (fig. 3). Even though the sawyer exercised greater care, delays occurred when the off-bearer had to handle small wedged boards, or when the refuse system clogged from the large volume of waste suddenly dumped into it.

The relationship between log soundness and sawing time can be expressed in another way: the time required to saw a given lumber

Figure 2. — Relationships between scaling diameter and sawing time for sound and defective maple logs.

Figure 3.—Large internal defects reduce lumber output per hour because of greater caution exercised and occasional delays.

volume. Such a comparison may have greater meaning for mill-owners because it considers the net lumber yield per log rather than the log size.

In using lumber volume yield as a basis for comparing sawing time differences between sound and defective logs, we found an even wider spread than we observed in the plot of sawing time by log diameter (fig. 4). The sawmill crew took about 1 minute longer to saw 100 board feet of lumber from internally defective logs than from sound logs. When net lumber yield per log was 300 board feet or more, the additional sawing time needed to produce equivalent yields from defective logs was about 1½ minutes.

Analysts appraising these findings may wonder if there was a difference in log grade between the sound and defective specimens.

Figure 4. — Relationships between lumber volume yield and sawing time per log for sound and defective maple butts.

Log-quality appraisals were based on the USDA Forest Service grading system as described by Ostrander (7). Grade rules were applied precisely. Thus some logs were downgraded because of excessive internal defect.

Although all three grades of factory logs were well represented in both sound and defective categories, neither the diameters nor the number of logs were similar. For this reason, we decided to evaluate the importance of log grade on sawing time by performing a separate regression analysis for each grade. Results showed that the better grades of logs took slightly less time to saw than the poorer grades of logs of the same size. However, differences in sawing time due to log grade were insignificant.

Since we found that such a large spread in sawing times was due to log condition, lumbermen will want to know if hollow butts can be sawed profitably. Most of them can be—if standards on the minimum amount of sound wood are followed. Of course, log profitability depends on purchase price and scaling accuracy as well as on lumber-production costs, as represented by sawing time.

The final decision to use or not to use defective logs rests upon only one factor: profit. If millowners believe they can make money from unsound butts, they will buy and saw them. But if operators are convinced they cannot make a profit from hollow or rotten logs, then foresters might just as well forget about improving the degree of utilization from such defective timber.

To give you a picture of the profit or loss from sound versus defective logs, we have used the gross and net dollar yields from each of the 219 sugar maple logs. In the graphs used to illustrate these value comparisons the sample is divided into the three factory-log grades developed by the USDA Forest Service. Because of the close link between log grade and lumber value per log, the log-grade breakdowns enable you to see the value trends more clearly than if the entire sample were lumped.

Please understand that the actual dollar values used in this comparison are not up to date. The lumber selling prices, the assigned costs for delivered logs, and the sawmill operating costs, are all based upon 1967 figures. Lumber selling prices used in this evaluation were based on listings in the Hardwood Market Report (Memphis, Tenn.) 48(45): 24 pp., Dec. 1967. They were: FAS—$270, IF—$260, 1 COM—$185, 2 COM—$85, 3A COM—$75, and 3B COM—$45. Stumpage and logging costs were set at $55, $70, and $85 per MBF for log grades 3, 2, and 1, respectively.

Current lumber prices are higher. So are the costs of delivered logs and the costs of operating a sawmill. Regardless of what cost and price figures are used, they are likely to be unreliable in the future.

Actual dollar values based on current prices and costs are not nearly as important as comparative values. We believe you need to picture the relationship between sound and defective logs more than you need to know the exact profit or loss from a particular log or group of logs. Therefore, we have developed regression lines that best fit the plotted data for individual logs. By comparing the differences between the lines, you will get a good picture of the comparative value of sound versus defective butts.

Sawmill operators will probably be interested only in the sawlog

dollar values obtained under actual operating conditions. There may be some researchers and analysts, however, who would like to consider potential log values if operating conditions had been different. For this reason, we are illustrating the comparative dollar value of sound versus defective logs for the following situations: (1) actual observed conditions, (2) elimination of log-scale inaccuracies, and (3) comparison of potential sawlog dollar values when both raw-material costs and lumber-production costs have been excluded.

Observed Conditions

Figure 5 shows the wide variation in net value per log for samples with similar characteristics. For sound logs of the same net scale and grade, it was common to find a range in net lumber value of $5 to $10 per log. For defective logs, this range in net

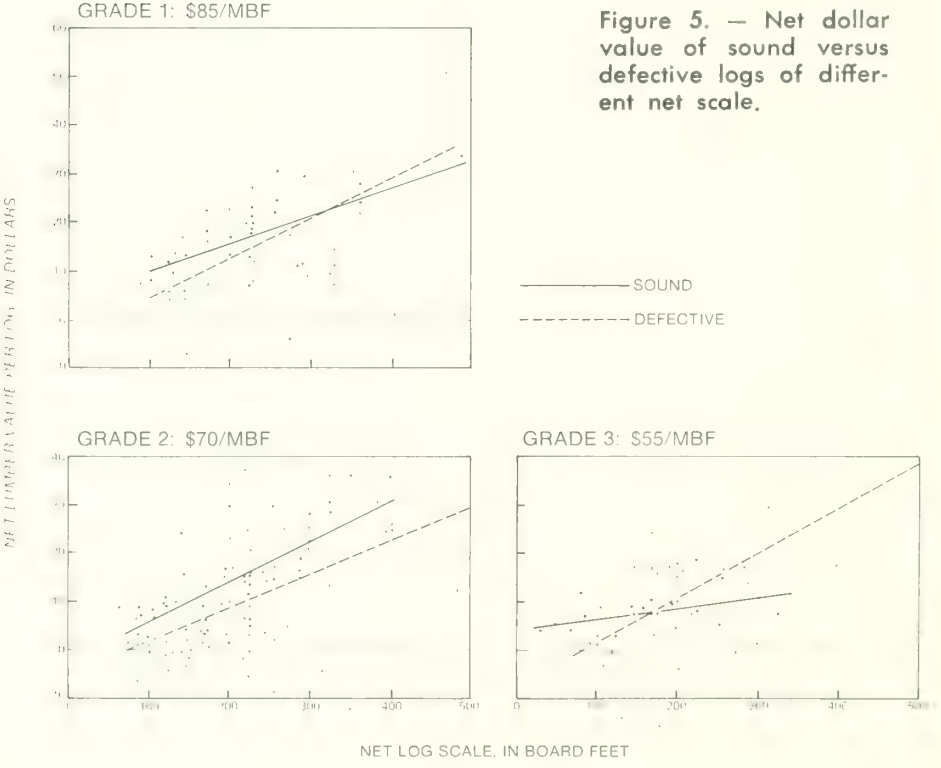


Figure 5. — Net dollar value of sound versus defective logs of different net scale.

lumber value was often greater: in a few instances it exceeded $30 per log.

Such broad ranges in net log value prevent us from making any uncompromising statement about the net worth of sound logs versus defective logs. However, our analysis of log values indicated that, in log grade 1, the average sound log was worth about $1.50 more than the average defective log. In log grade 2, the average sound log had about a $5 greater net value than the average unsound log. In log grade 3, however, the situation was reversed: the average defective log was worth about $3 more than the average sound log.

We expected the sound logs to be more valuable because: (1) the scaler made a larger overestimate of net volume in defective logs, and (2) the sawyer took longer to cut the same volume of lumber from defective logs. In fact, we were surprised to find that the differences in net value between sound logs and defective logs were not greater. However, the low-grade lumber in the heart center rarely sells for its cost of manufacture plus stumpage, so that is why there was not much difference in value between sound logs and defective logs where some or all of this low-grade material was missing.

The defective logs tended to have larger diameters than the sound logs. Thus the unsound logs had a larger volume in the better lumber grades and were inherently more valuable. That's why regression lines for grade 1 logs crossed near 300 board feet. Regression lines representing the least-squares fit for grade 2 logs did not cross because there were enough big sound logs to balance the high values received from the big unsound logs.

Now consider the unusual log-value relationship for the samples in log grade 3. Why did the average defective log have a higher net value than the average sound log? Differences were obviously not due to scaling inaccuracies or higher lumber production costs —otherwise the value relationships would have been reversed.

We believe that the larger diameters of the defective logs were partly responsible for the higher log values. Generally, the bigger the logs, the higher the proportion of lumber in the upper grades. The following tabulation substantiates this premise. Defective

grade 3 logs with an average net volume of 202 board feet had 51 percent in 1 Common and Better lumber. Sound grade 3 logs with an average net volume of 158 board feet had 46 percent in 1 Common and Better lumber:

Lumber grade	*Sound logs (percent of yield)*	*Defective logs (percent of yield)*
FAS	6.2	13.2
IF	12.5	8.2
1 COM	27.2	29.3
2 COM	25.8	26.0
3A	18.8	13.1
3B	9.5	10.2

This particular sample of grade 3 logs was classified grade 3 primarily for one reason: the frequency and location of surface defects. On big logs, surface defects in the same face may be only 2 feet apart longitudinally. However, the sawyer may be able to cut some relatively clear boards between knots that are spaced far apart radially. That may be why the yield in the upper lumber grades was greater than the yield normally obtained from grade 3 logs. Furthermore, the log grade rules permit grade 2 logs with 51 to 60 percent cull to be classified as grade 3 logs even though the maximum cull deduction for grade 3 logs is 50 percent. This provision may be one reason why the defective grade 3 logs had a higher net value than sound grade 3 logs—some of the defective logs had grade 2 surface characteristics.

Elimination of Scaling Inaccuracies

Suppose that a company scaler and sawmill crew worked in such perfect harmony that there was no difference between the log scale and the lumber volume sawed. How would such a relationship affect the net value of the lumber sawed from sound and defective logs?

For the log sample used in this study, precision scaling would have increased net sawlog values. The value increase would have been about $1.55 per MBF for sound logs and about $3.70 per MBF for defective logs. Precision scaling also would have the effect of reducing some of the irregularities observed in our plot of sawlog dollar value over net scale. For example, some of the large sound logs would no longer be worth less than some of the

unsound logs of equal net volume. Hence, regression lines representing sawlog dollar value over lumber yield (perfect log scale) show a more parallel relationship between sound and defective logs in the same grade.

Why would there be an increase in net log value from precision scaling? Under actual practice, the company scaler overestimated net volume in this group of logs. Therefore the company paid the logging contractor for more volume than they actually sawed. They also paid more for the stumpage. If both stumpage and logging had been paid for on the basis of the exact volume sawed, raw material costs would have been less, and the resulting net log values would have been higher.

This example shows why millowners need to know the level of scaling accuracy practiced at their respective facilities. A consistent overestimate of net volume will require a downward price adjustment to keep raw-material costs in line. Of course, an underestimate of net volume has the opposite effect. Thus a consistent overrun permits owners to raise log-purchase price if stumpage competition and producers' harvesting costs require it.

POTENTIAL SAWLOG VALUE

For the final evaluation of sawlog value, we eliminated both the cost of delivered logs and the cost of lumber production as measured by sawing time. Thus the comparisons between sound and defective logs are based on the relationship between *net* lumber *volume* mill tally and *gross* lumber *value* per log. We have designated this association the board foot-dollar ratio.

The link between net lumber volume and gross lumber value per log represents an unreal situation. You cannot eliminate costs and get an accurate picture of individual log value. However, neither can you assess the inherent worth of a log if you base your evaluation of production costs on highly variable sawing times. Nor can you correctly evaluate potential sawlog worth if you use purchase prices that are based on inaccurate scale estimates. Therefore, to get a true measure of the *potential* value of a log, you

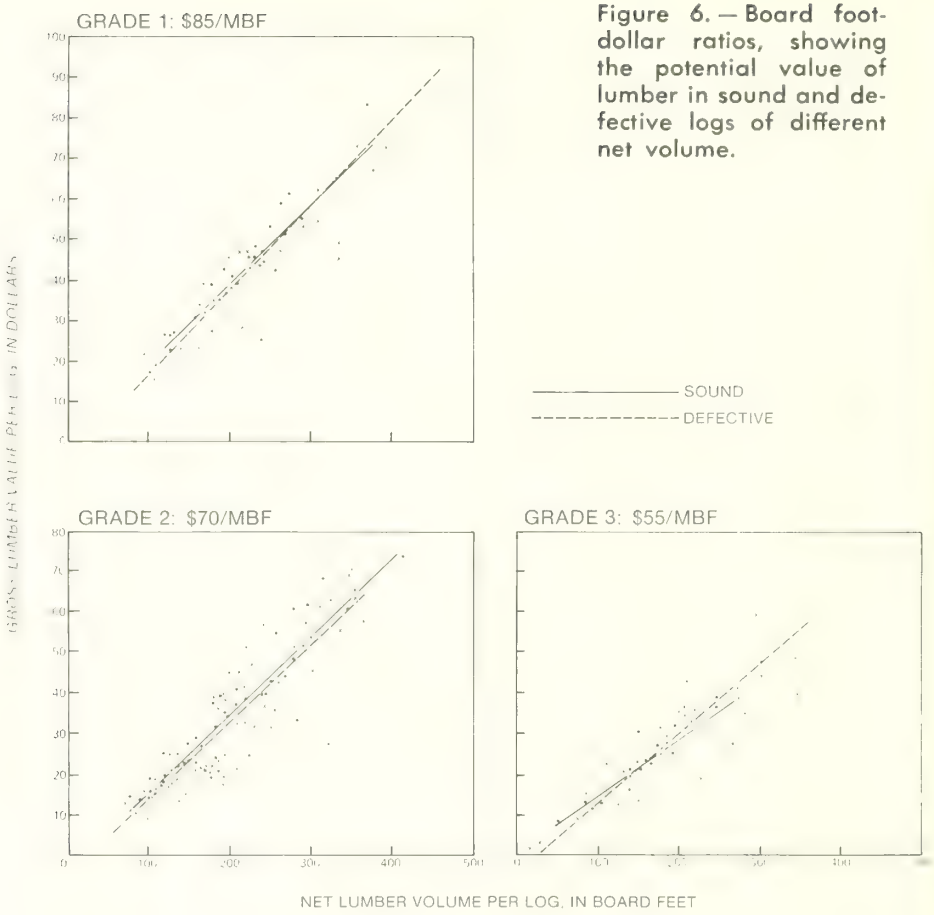


Figure 6. — Board foot-dollar ratios, showing the potential value of lumber in sound and defective logs of different net volume.

should use some evaluation technique like the board foot-dollar ratio.

The regression lines (fig. 6) illustrate the striking similarity in gross dollar value between sound and defective logs of the same grade. Apparently a given quantity of lumber sawed from a defective log is worth just as much money as an equivalent volume sawed from a sound log. When the ratio between gross dollar value and net lumber volume is expressed on a thousand-board-foot basis, the resemblance between sound and defective logs is conspicuous:

Log grade	*Sound logs*	*Defective logs*
1	$194	$192
2	172	164
3	144	152

In the foregoing tabulation, you will notice that sound logs in grades 1 and 2 had a slightly higher value than defective logs. In log grade 3, however, lumber from the defective logs was worth more. This value relationship corresponds closely with the log value associations observed under actual operating conditions.

Although the board foot-dollar ratios have no immediate practical significance, both lumbermen and researchers should be interested in the value associations. Mill operators will recognize that they can get just as good lumber from defective logs even though production is slower and more costly. Researchers, on the other hand, will be encouraged to seek for improved techniques for recovering this high-grade material that is now so frequently wasted.

Lumbermen considering the use of internally defective butt logs should be prepared to face some of the technical questions that might arise when using such raw material. Millowners should understand how defective logs affect such operations as truckload volume, scaling precision, and sawing time. Then they can decide whether the net dollar yields from unsound logs will offset some of the special problems that will be encountered.

Trucking defective butts had little effect on the net scale per load. There was less than 10 board feet difference between loads of currently merchantable logs and loads containing both merchantable and defective logs. Thus hauling costs were unaffected by the acceptance of unsound butts.

Scaling precision on individual logs was extremely variable, regardless of log condition. Although overestimates and underestimates nearly balanced one another, underrun for the entire sample amounted to 1.7 percent for sound logs and 3.8 percent for defective logs. With this underrun, log costs per board foot of lumber yield were higher than expected. If the company scaler had been able to precisely estimate the actual net lumber yield,

then the cost of delivered logs, including stumpage, would have been reduced about $1.55 per MBF for sound logs and about $3.70 per MBF for defective logs.

Sawing times for defective logs were noticeably greater than the sawing times for sound logs of similar size. Furthermore, the spread in sawing time between sound logs and defective logs was even wider when the comparisons were based upon an equivalent volume of lumber sawed from both types of logs. One minute more of headsaw time was needed to saw 100 board feet of lumber from defective logs than from sound logs. And 1½ minutes more of headsaw time were needed to saw 300 board feet of lumber. Naturally, the additional sawing time needed for equivalent lumber production from unsound logs sharply increased milling costs.

Net dollar yields from sound logs in grades 1 and 2 were higher than the net dollar values obtained from defective logs of similar volume and grade. The difference in net value between average sound and unsound logs was $1.50 for grade 1 logs and $5.00 for grade 2 logs. For grade 3 logs, however, the average unsound log was worth about $3.00 more than the average sound log.

The potential value of a given volume of lumber cut from either sound or defective logs was nearly identical. Thus, the dollar value of 1,000 board feet of lumber sawed from defective logs was approximately equal to the dollar value of the same quantity of lumber sawed from sound logs. But this similarity, called the board foot-dollar ratio, applies to gross value or selling price. Such an evaluation disregards production costs and scaling inaccuracies that influence raw-material costs. Nevertheless, the high inherent value of lumber in defective logs should tempt lumbermen to use more of this type of raw material rather than waste it.

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by M. D. Ostrander

Identification & Evaluation of DEFECTS IN EASTERN WHITE PINE Logs & Trees

U.S.D.A. FOREST SERVICE RESEARCH PAPER NE-190
1971

NORTHEASTERN FOREST EXPERIMENT STATION, UPPER DARBY, PA.
FOREST SERVICE, U.S. DEPARTMENT OF AGRICULTURE
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Identification & Evaluation of DEFECTS IN EASTERN WHITE PINE Logs & Trees

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THE GRADE of eastern white pine lumber is determined primarily by the condition, size, and frequency of natural blemishes characteristic of the species. These include bark pockets, cross grain, rot, knots, pitch pockets, and shake. Mismanufacture and seasoning defects also affect lumber grade.

Many of the natural defects in lumber can be related to external indicators on the log or tree. For example, limby logs result in knotty lumber, and crooked logs result in cross-grained lumber. Objective measurement and evaluation of these external indicators are essential for accurate application of any log- or tree-grading system.

This guide, based on our latest knowledge about the identification and evaluation of surface blemishes on eastern white pine logs and trees, was prepared for use as an aid in applying the standard eastern white pine log grades.

Unless otherwise stated, the significance of the various blemishes or imperfections defined and described in this guide apply over the commercial range of the species. The end product considered in evaluation is standard yard lumber as defined by the Northeastern Lumber Manufacturer's Association and the Northern Hardwood and Pine Manufacturer's Association.

FACTORS THAT AFFECT QUALITY

Several measurable log factors affect the quality and value of lumber that can be cut from eastern white pine logs. These are (1) log diameter and length, (2) log straightness, and (3) visible imperfections on the surface of the log.

Log diameter and length.—Longer lengths and wider widths of lumber usually command premium prices. Certain lumber grades carry minimum length and width restrictions. Such premium-price material cannot be produced from small or short logs. In addition, restrictions on percentages of short or narrow

lumber in a shipment are often imposed upon the lumber producer.

Straightness.—Straight logs generally yield both the greatest volume and the highest quality of lumber. Crooked logs yield less volume and lower quality.

Visible imperfections on log surface.—These log defects can be divided into two main categories: grading defects and scaling defects. *Grading defects* are imperfections that affect the quality of lumber produced from a log. They include all imperfections relating directly to knots and other lumber defects that are generally not removed in lumber manufacture. *Scaling defects* are imperfections that reduce the quantity of sound wood in a log. These defects are usually removed in primary manufacture of lumber and are considered in determining net volume of a log or tree.

The distinction between the two types of log defects is not always clear. Reduction of volume scale does not necessarily remove the total effect of certain scalable defects such as red rot or shake. Limited amounts of these defects are permissible and often are left in lumber, consequently lowering its utility or value. Therefore, when such imperfections are not limited to certain portions of the log they must also be considered as grading defects.

In general, the seriousness of a log surface imperfection depends on the specifications for the product (lumber, veneer, etc.) into which the log is to be manufactured. Eastern white pine lumber is graded under yard lumber rules, in which each recognized grade within the system has a somewhat different end use. For this reason, nearly all measurable log-surface imperfections that result in degrading the underlying lumber are considered grade defects. A few, because of their minor effects on lumber quality, can be disregarded in log-grading. Examples of such minor imperfections are pin knots and bird peck.

Log imperfections are divided into three major classes: (1) those that generally affect log quality (grading defects); (2) those that generally affect net log-volume determination (scaling defects); and (3) those that can usually be ignored in both grading and scaling.

The most important grading defects are those that directly and consistently influence the quality of lumber that can be produced from a log. They include log knots; holes and overgrown log knots usually related to lumber defects such as knots, bark pockets, and holes; and to other less frequent but damaging imperfections such as sweep, crook, rot, and shake. The various visible grading defects common to eastern white pine are discussed individually and in descending order of importance.

Log Knots

The term "log knot" is used to describe live limbs, dead limbs or dead limb stubs, limb sockets or holes, overgrown limbs, or any other indication of where a limb grew. All these conditions result in a knot in the underlying wood and consequently a knot in the lumber produced from the log.

Log knots with average diameters of ½ inch or less are not considered as grading defects (fig. 1). Such knots result in pin knots in lumber, which are permissible in all grades of lumber. Although all log knots over ½ inch in diameter are degraders, their size, condition, and position significantly influence the grade of the log.

Log knots are the most common and important grading defect

Figure 1.—Dead log knot ½ inch in diameter on a 14-inch log. All knots of this size or smaller are disregarded in grading.

in eastern white pine. The grader must be able to accurately evaluate the types of log knots common to the species. For purposes of evaluation in log-grading they are classified as follows:

Live log knots.—These are knots intergrown with the surrounding wood at the surface of the log, giving no indication of decay (fig. 2). They result from living or recently dead branches or limbs. In standing timber the latter are usually identifiable by the presence of bark and small twigs still adhering to the limbs. Size measurement of live log knots includes only the average diameter of the red or heartwood portion of the limb at a point flush with the bark surface of the log.

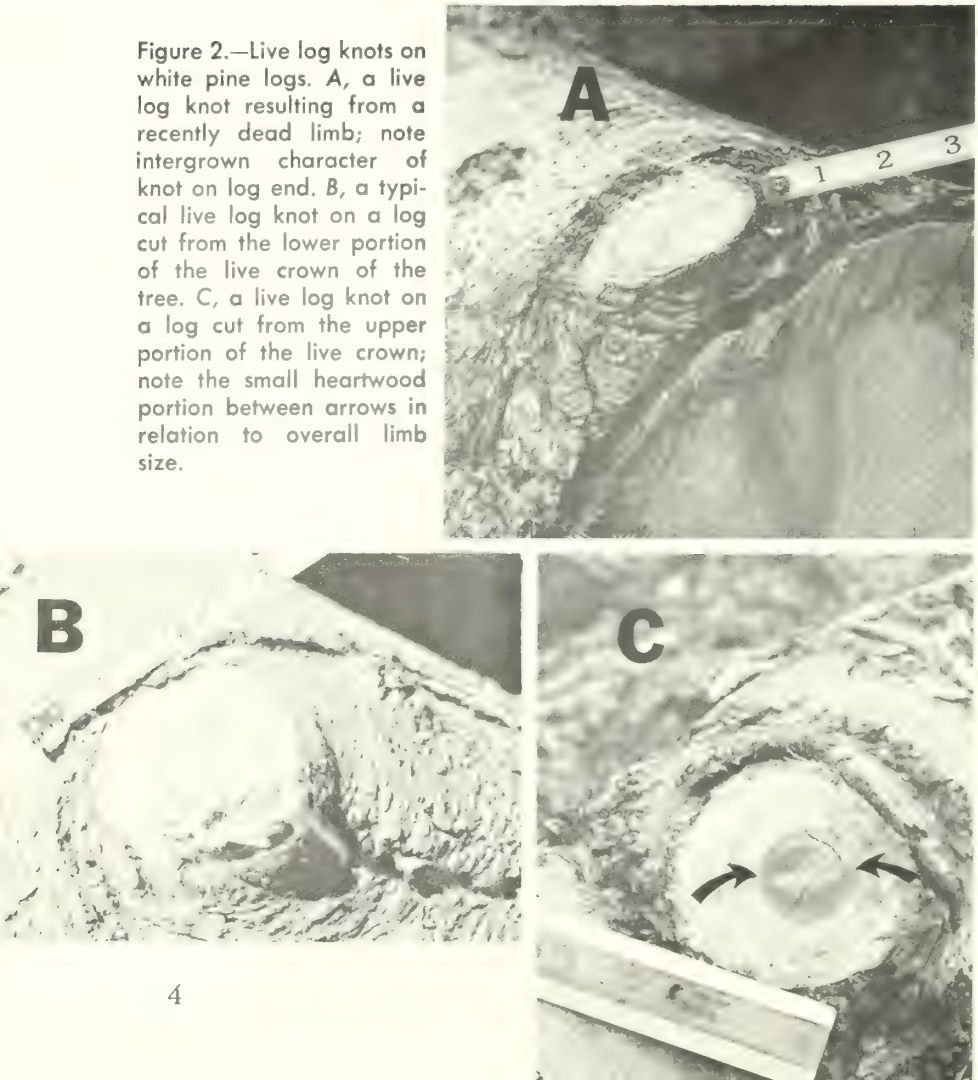


Figure 2.—Live log knots on white pine logs. *A*, a live log knot resulting from a recently dead limb; note intergrown character of knot on log end. *B*, a typical live log knot on a log cut from the lower portion of the live crown of the tree. *C*, a live log knot on a log cut from the upper portion of the live crown; note the small heartwood portion between arrows in relation to overall limb size.

In grading *butt* logs in standing trees for tree-grading purposes, these diameters must be estimated. As a guide, the knot size of recently dead limbs can be approximated closely by estimating the average diameter inside bark at a point just beyond the limb collar. Seventy-five percent of this diameter will closely approximate the knot size of live limbs. This same approach should also be applied to any epicormic limbs that are found on the grading section of a tree.

Dead log knots.—These result from dead limbs or stubs not completely intergrown with the surrounding wood at the log surface (fig. 3). They may be sound, with little or no sign of deterioration; or they may show moderate to severe signs of deterioration due to weathering and decay. The latter are sometimes classified as unsound dead log knots. However, because of difficulty in consistently differentiating between the two, and the resulting knot character in the underlying wood, they are lumped together as dead log knots. Live log knots containing rot should also be treated as dead knots for grading purposes.

Size of dead knots is defined as the average diameter of the entire dead limb material present, excluding any surrounding callus tissue. Dead log knots usually result in black or encased knots in the lumber.

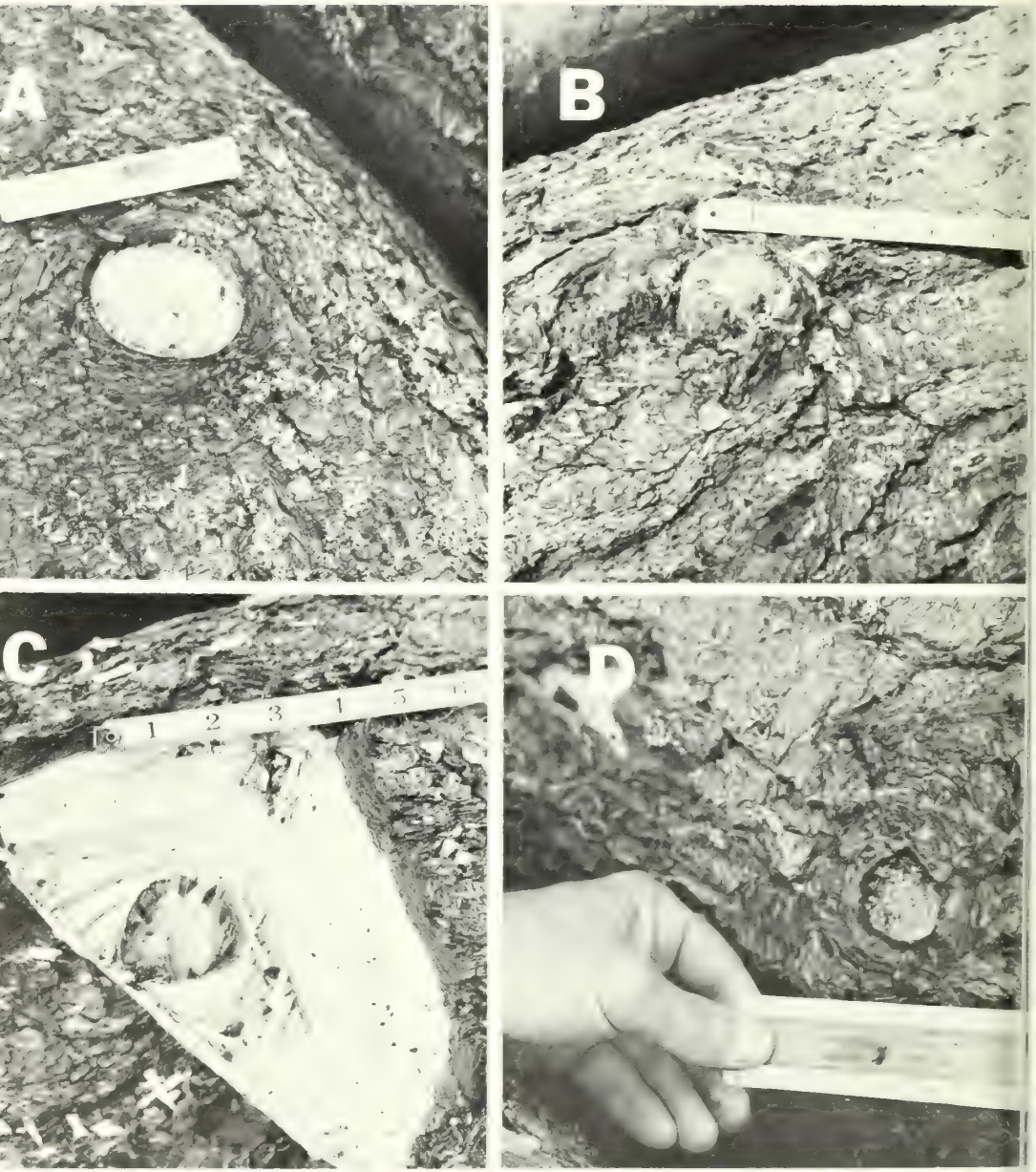


Figure 3.—Dead log knots on white pine logs. *A*, a sound dead log knot showing no signs of deterioration. *B*, a dead log knot showing moderate signs of deterioration. *C*, the same knot chopped out to a depth of 3 inches and still showing encased condition. *D*, an unsound dead knot showing advanced deterioration.

Overgrown log knots.—These are scars left in the bark by a limb that has been completely overgrown but is clearly outlined by circular or similar configurations in the bark (fig. 4). Overgrowths caused by other bark injuries usually do not possess the typical circular pattern or pucker in the bark. They can either be ignored or can be treated as a scaling defect only.

Because white pine does not develop much clear bole length in early maturity, all but the smaller limbs (up to 1 inch diameter)

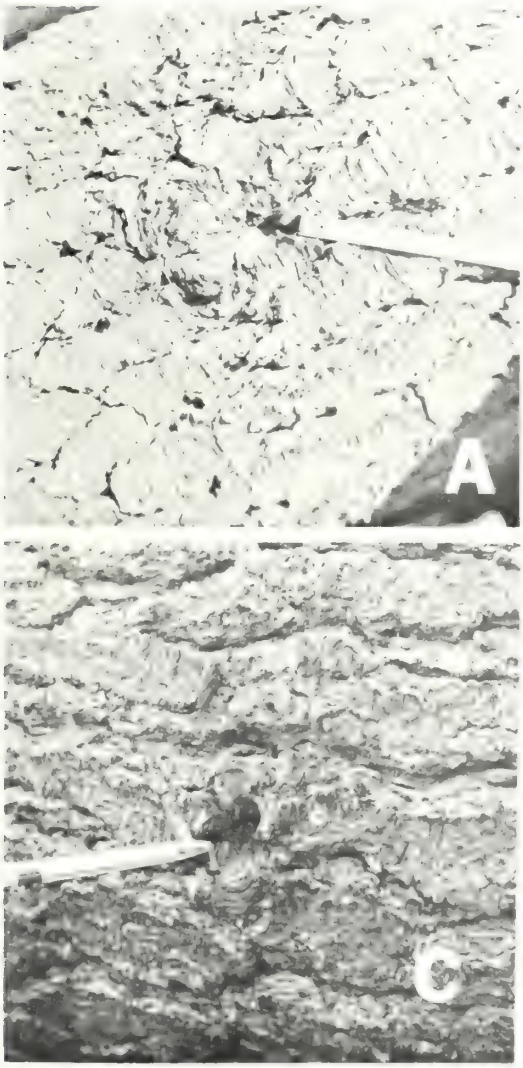


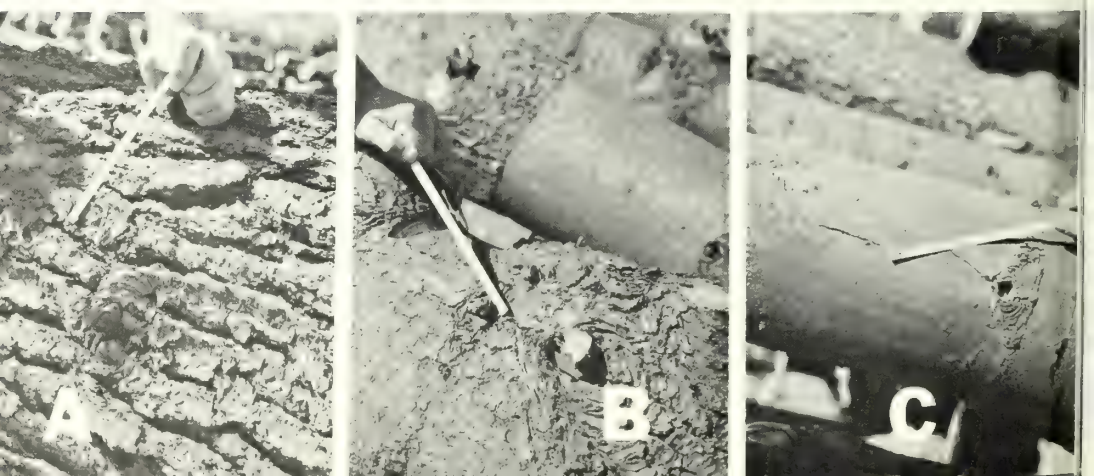
Figure 4.—Log knot overgrowths in white pine logs. *A*, a recently overgrown log knot. *B*, a log knot of older origin (later stage). *C*, the overgrowth resulting from a log knot ½ inch or less in size; such an overgrown knot can be disregarded in grading as it is less than 1 inch in diameter as measured parallel with the axis of the log.

persist for many years unless pruned. Even under excellent growing conditions, many trees retain a few limb stubs in the butt log. It is generally safe to assume that the size of a knot underlying an overgrowth is no larger than limbs or limb stubs still present on the log within the same or adjacent branch whorls. Overgrowths or puckers 1 inch or less in diameter (measurement made parallel with the long axis of the log) can generally be considered as indicators of underlying knots ½ inch or less in diameter, and should be disregarded. Overgrowths measuring more than 1 inch in diameter should be treated the same as 1-inch dead log knots in grading unless visible adjacent limb stubs indicate otherwise.

General log-knot considerations.—The occasional dead log knots encountered beyond the first whorl of live log knots should be considered as live log knots in grading. To qualify as a live knot whorl, at least ½ the log knots in the whorl must qualify as live. Subsequent whorls must also meet the same limitation.

Bark character is sometimes useful in a quick evaluation of log-knot condition in eastern white pine (fig. 5). Generally the majority of log knots in rough-bark white pine logs are dead. In logs with an intermediate type of bark, log knots vary from dead to live. And in smooth-bark logs the majority of log knots are live.

Figure 5.—Bark character is usually related to knot condition. A, a rough-bark white pine log with dead log knots. B, an intermediate-bark white pine log with both live and dead log knots. C, a smooth-bark white pine log with predominately live log knots.



Weevil Injury

Injury caused by the white-pine weevil (*Pissodes strobi*), particularly in the Northeastern United States, is a serious and common grading defect of eastern white pine. It is unusual to find a stand of white pine timber in this area that has not suffered significant losses in quality due to weevil injury.

Weevil attack in white pine is usually limited to the terminal leader (growing tip) of the tree. It causes death of the growing tip and subsequent deformity (fig. 6). Evidence of weevil injury in logs or trees can usually be recognized by moderate to severe crook or fork at the point of injury, combined with abnormally large and acute-angled branching. Crook is usually more severe in small logs or trees, and is less evident in larger logs (fig. 7).

Figure 6.—White-pine weevil injury. A, weevil injury in the terminal growth of a sapling; the dominant lateral branch has turned upward to replace the dead tip. B, weevil injury in the bole of a white pine as evidenced by a crook and abnormal branching at the point of injury.

Figure 7.—Weevil crook in white pine logs. *A*, a severe crook in a small log. *B*, a moderate crook in a larger log.

Occasionally the dead leader persists for many years as a small branch stub, recognizable by larvae galleries in the pith and surrounding wood. Logs showing any of these characteristics are considered weeviled, and they are automatically limited to grade 3 or poorer.

Weevil injuries in white pine logs lower resulting lumber values in several ways (fig. 8). The coarse acute-angled knots and severe cross grain at weevil crook often reduce lumber grade, and red ring rot entering through the dead weeviled tip often causes additional lumber degrade.

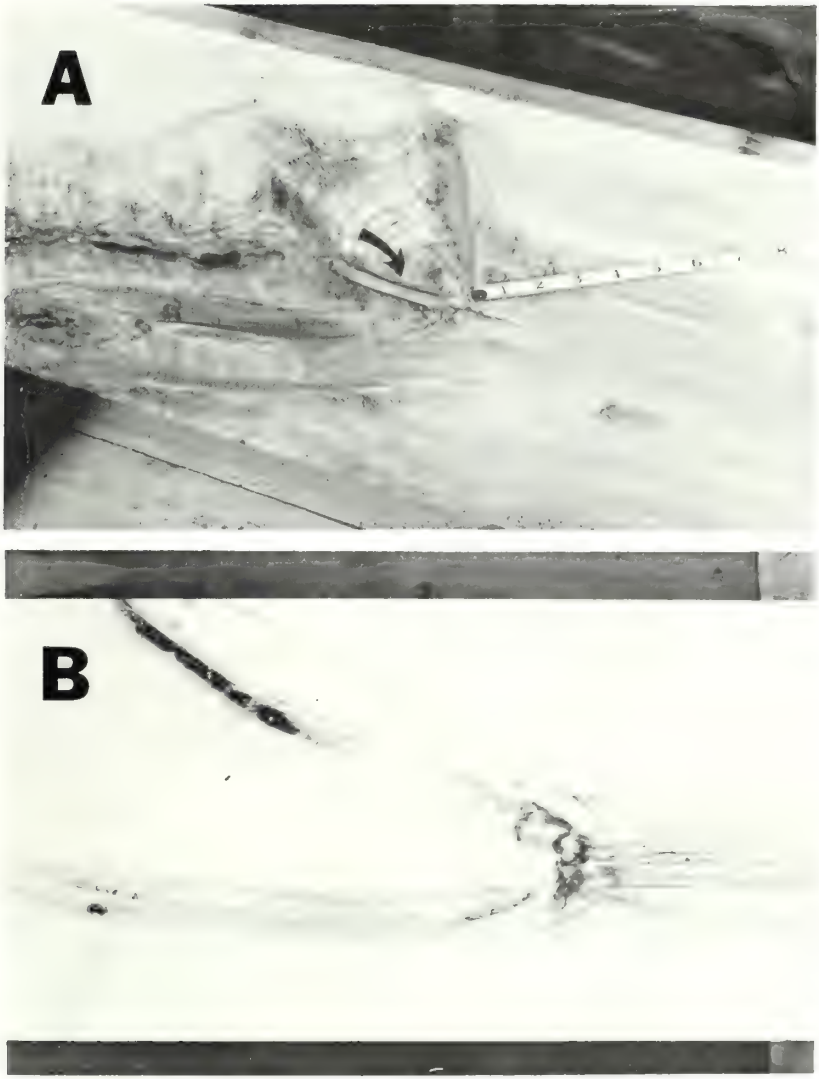


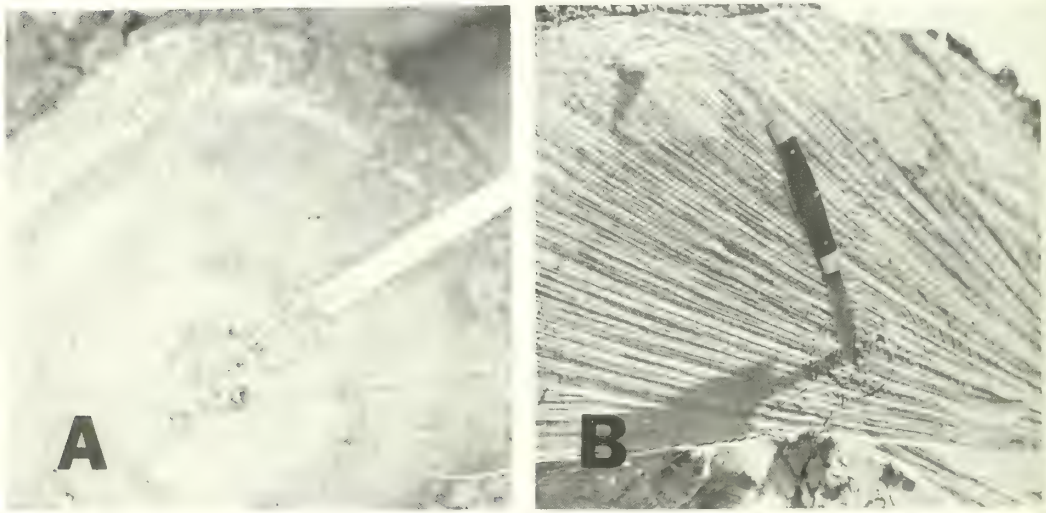
Figure 8.—Lumber defects due to weevil injury. *A*, severe cross grain and large coarse angular knots occurring at the point of weevil injury; the old weeviled tip is indicated by the arrow. *B*, red rot streak surrounding the pith at the point of weevil injury.

Red Ring Rot and Rot Indicators

Red ring rot (*Fomes pini*) causes serious degrade in eastern white pine, particularly in older trees and those that have been attacked repeatedly by white-pine weevil. Although scaling deductions are necessary for measurable advanced stages of decay, less advanced stages of the fungus decay and discoloration are often left in the lumber, thereby lowering its grade and value.

Red ring rot is usually detected in logs by inspecting log ends (fig. 9). Scale deduction is made on the basis of Forest Service standard scaling procedures; reduction of log grade depends upon the location and extent of the affected area. If visible signs of the rot—incipient or advanced—are limited to the heart center of the log (the central core of the log, having a radius equal to 1/5 of the log diameter) or extend beyond the heart center in only one quarter of either end of the log, no grade reduction is necessary. If evidence of rot extends outside the heart center in two or more

Figure 9.—Red ring rot (*Fomes pini*) showing on ends of white pine logs. A, typical formation following annual growth rings. B, red ring rot confined to heart center of log. Evidence of weevil injury was present on this log.



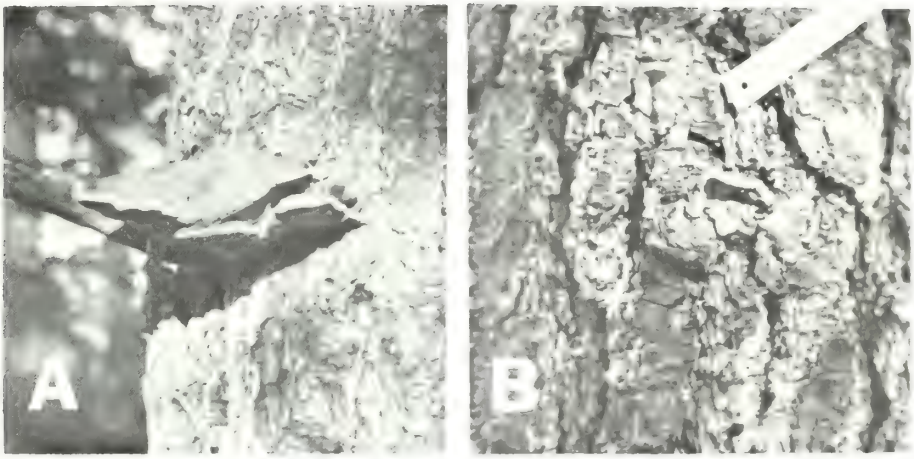


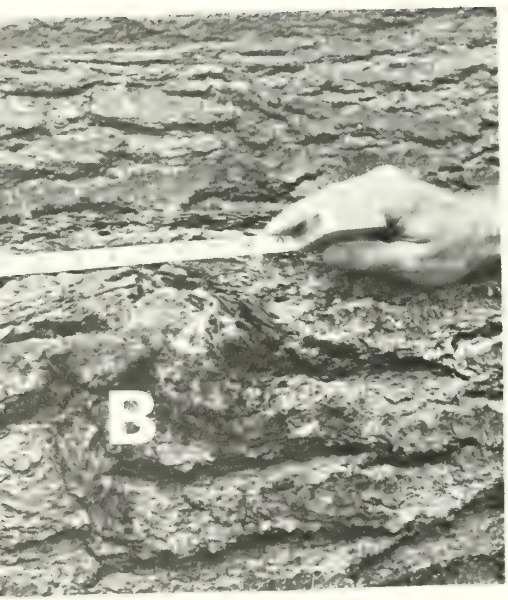
Figure 10.—Conk forms of red ring rot fungus (*Fomes pini*) on eastern white pine. *A*, a bracket-shaped perennial sporophore. *B*, a small scab-shaped conk with narrow bracket line margin. The latter form, the most common in the Northeastern States, is difficult to detect in the upper portion of standing trees.

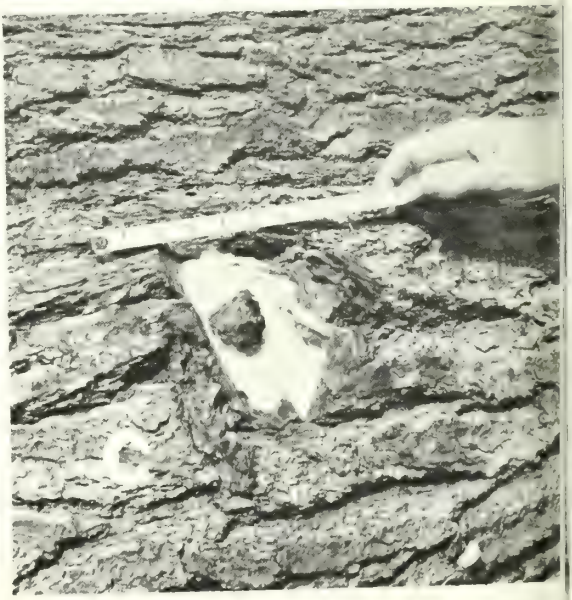
quarters of the log ends, grade reduction is necessary in accordance with the log-grade specifications.

In standing trees and occasionally in bucked logs, the presence of red ring rot may not always be evident—particularly in its early stages. However, advanced stages of the rot are usually indicated by the presence of conks—the fruiting bodies of the fungus. Such conks, found on the bole of the tree (fig. 10), are fibrous or fleshy protrusions of variable shape and structure. Other evidence of this fungus is the punk knot or blind conk, a nonfruiting tissue of the fungus (fig. 11).

Both of these conditions usually signify advanced stages of red ring rot in the tree or log, the extent of which depends on the age of the infection and age and vigor of the tree. Serious volume loss is usually indicated, and the presence of numerous conks or punk knots throughout the bole of the tree usually indicates a cull tree. The presence of conks or punk knots on the bark surface of logs—regardless of whether rot is in evidence on log ends—constitutes a grading defect.

Figure 11.—Punk knots or blind conks of *Fomes pini* on eastern white pine. A, a blind conk on a mature tree, indicated by arrow; note the pitch streak from the base of the swollen knot overgrowth. B, a close-up of a punk knot. C. the punky fungus material underlying a punk knot.





Although not infallible, the presence of bleeding log knots or limb stubs in standing trees is often a reliable indicator of moderate to advanced stages of red ring rot infection. Whenever several to many bleeding limb stubs are in evidence, recognizable by white pitch streaks on the bole of the tree, the grader should carefully inspect the bole of the tree for possible presence of conks or punk knots (fig. 12).

Holes over 1 inch in diameter caused by woodpeckers are good indicators of red rot infection (fig. 13). If other evidence of rot is lacking, the effect of such holes can be treated the same as conks in grading. Woodpeckers making such holes are usually in search of carpenter ants or other insects that have invaded the rot-infected portion of the tree bole. These holes usually occur below the live crown of the tree.

Figure 12.—Whitish pitch streaks caused by bleeding limb stubs are often a good indicator of red ring rot infection.

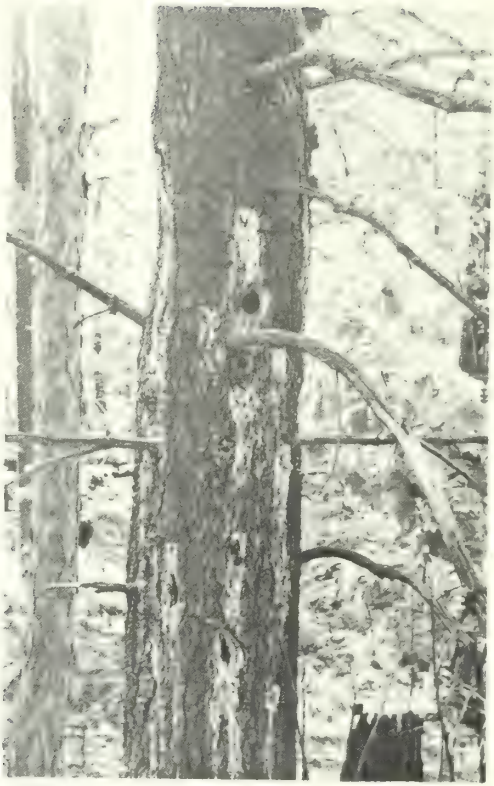


Figure 13.—Holes caused by woodpeckers in search of insects. They usually indicate presence of red ring rot or other rot-causing fungi.

Ring Shake

Ring shake is a tangential separation of fibers along the annual growth rings. It may be found as a complete or partial circle in or outside the heart center of the log (fig. 14).

White pine trees less than 100 years old are usually free of

Figure 14.—Ring shake in eastern white pine—a serious degrading defect in old-growth timber.

serious ring shake. In older trees, particularly in the Lake States, shake is a serious grading defect in old-growth timber. Severe shake, characterized by readily discernible openings between growth rings, requires scale deductions because much of the affected lumber is low grade or cull. In many cases, however, ring shake is barely detectable; and affected lumber, although intact, has less strength and utility and therefore must be reduced in grade.

Whenever ring shake occurs outside the heart center of the log it is considered as a grading defect and is treated in the same manner as red rot. Grade reduction depends on the number of log end quarters affected. In standing trees it is impossible to detect and its occurrence must be based on knowledge of timber in the area under consideration.

Sweep and Crook

Sweep is a gradual bend in a log or tree: crook is an abrupt bend (fig. 15). Both may originate from the damaging effects of wind, snow, sleet, or other mechanical causes, or from damage or loss of terminal growth as in white-pine weevil injury.

Figure 15.—Lack of straightness in white pine logs seriously affects lumber quality. A, sweep of 6 inches in this otherwise grade 2 log has lowered it to grade 3. B, crook due to weevil injury seldom further reduces grade unless total scale deduction exceeds 50 percent.

Sweep, in addition to being a scaling defect, is a grading defect whenever it exceeds the limits indicated by the grade specifications.

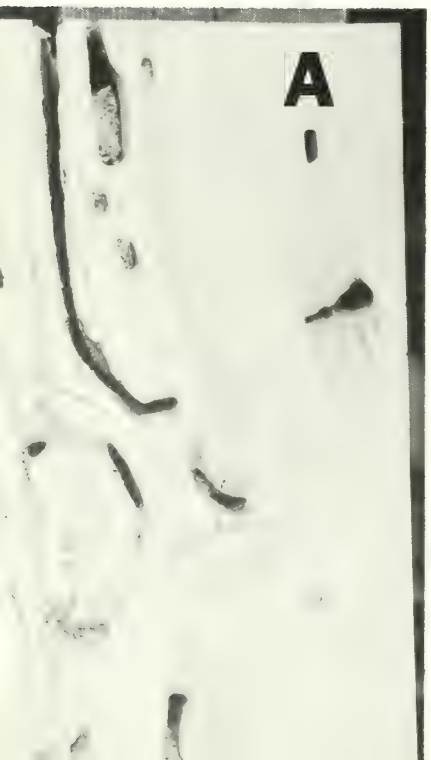
Crook may be a grading defect as well as a scaling defect if the limitations of grade are exceeded.

Lumber sawed from logs with sweep or crook is usually of lower grade because of the abnormal distribution of heart center defects and the effect of cross grain, which affects the strength of the piece. If crook is due to weevil injury, it does not further affect log grade unless is exceeds the merchantability limits of the log.

Insect Damage and Stain

Various bark- and wood-boring insects such as ambrosia beetles, pine borers, pine sawyers, carpenter ants, and bark beetles attack injured or decadent white pine trees or infest freshly cut logs in spring and summer. In many cases blue stain accompanies these infestations.

Carpenter ants generally make their initial attack in unsound butt wounds of living or dead trees and in such instances do not further degrade the logs or trees. Initial damage is often un-



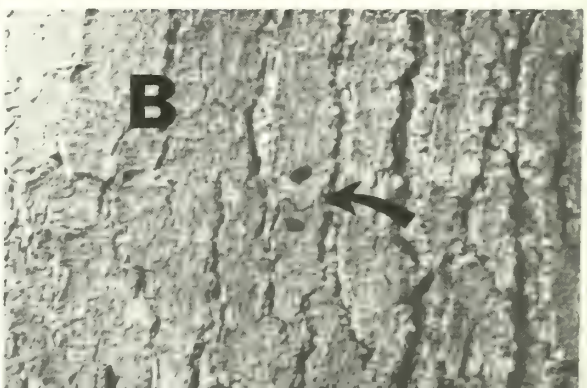


Figure 16.—Carpenter ant damage in logs and lumber. A, carpenter ant galleries in the sound heartwood of white pine lumber. B, carpenter ant "windows" at breast height in a white pine tree.

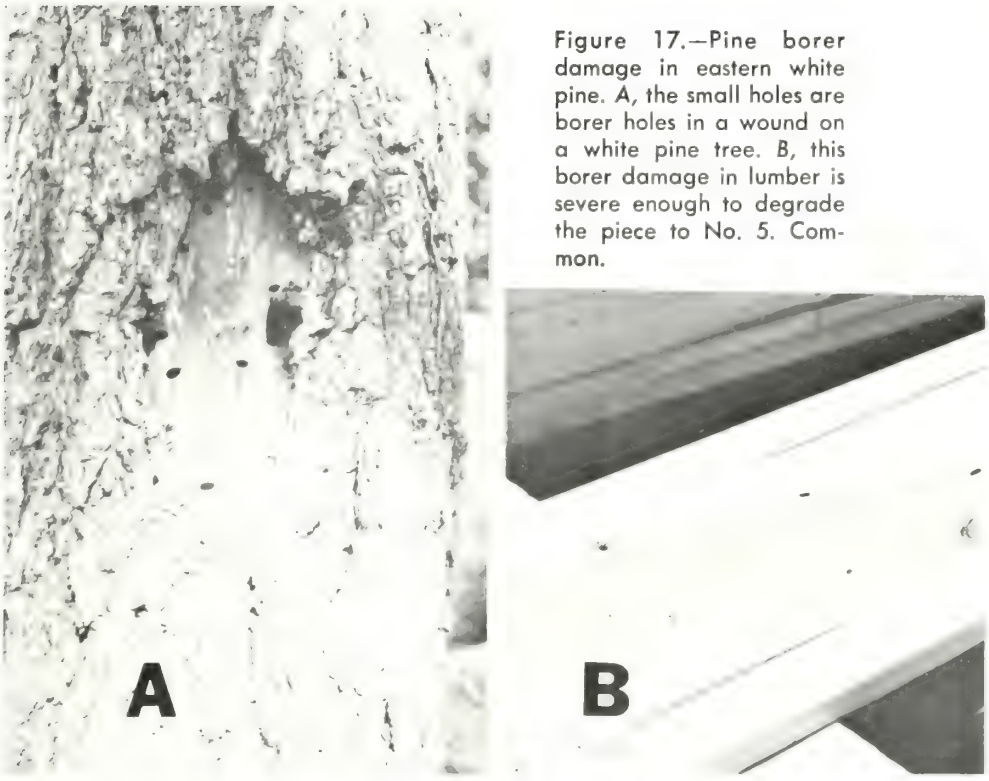


Figure 17.—Pine borer damage in eastern white pine. *A*, the small holes are borer holes in a wound on a white pine tree. *B*, this borer damage in lumber is severe enough to degrade the piece to No. 5. Common.

detected by inspection. However, as further development of the ant colony continues, concentric longitudinal galleries are cut into adjacent sound heartwood, which may add to the original damage (fig. 16). In advanced stages their presence can usually be detected by small access holes, called windows, leading to underlying nests.

Ambrosia beetles attack dying trees and freshly cut logs. Although difficult to detect in standing trees, unless the infestation is severe, they can be identified readily in the resultant lumber by small pin holes surrounded by fungus-darkened wood. Initial attack in trees or logs is through the bark or at old wounds.

Pine sawyers and other flat-headed wood borers usually attack recently killed trees and freshly cut logs. Evidence of infestation is usually apparent by entrance channels and accumulation of frass. The holes are 3/16 to 1/2 inch in diameter (fig. 17).

Wood-boring insect damage on white pine logs usually lowers the grade of the infected lumber to No. 4 or 5 Common, whereas carpenter ant damage usually results in complete loss of affected areas and therefore requires scale deduction.

Bark beetle damage caused by *Ips* and *Dendroctonus* beetles is usually limited to the inner bark and slab zone. However, moderate to heavy blue stain usually results from such attacks, and lumber from such logs may be lowered in grade because of stain.

The evidence of insect infestation or heavy blue stain in the log ends outside the heart center should be dealt with in the same manner as red rot and shake. When evidence of insect damage is apparent from the bark surface, degrade the log as if a conk or punk knot were present. Whenever damage results in cull material, a log scale deduction must also be made.

SCALING DEFECTS

In addition to those imperfections resulting in quality losses (degrade) as well as possible volume losses in white pine logs or trees, there are several common imperfections in white pine that usually require scale reduction without degrade.

Brown Cubical Rot

This heart rot, also known as red brown butt rot, is caused by the fungus *Polyporus schweinitzii.* It usually enters through the roots of white pine trees and progresses upward into the heartwood of the butt of the tree (fig. 18). It seldom extends up the tree more than 8 or 10 feet. There may be no external evidence of the rot in its early stages. but in advanced stages conks may be evident on the butts of infected trees, or on the ground nearby, coming up from decayed roots. A conk appears as a thin bracket, circular in shape, sunken in the center, with a velvety upper surface when fresh.

Incipient stages of decay in the wood may be inconspicuous; but as decay progresses, the color darkens and the wood becomes red-brown in color, and brittle; and on drying, it breaks into large cubes. The rot column is normally conical from the base of the tree upward and is generally circular in cross-section.

Figure 18.—Brown cubical rot (*Polyporus schweinitzii*) in white pine is usually limited to the heart of the butt log and can be treated as a scaling defect only. *A* and *B*, typical appearance of moderate to advanced stages of rot in the butt ends of butt logs. *C*, fruiting bodies of the fungus at base of tree. *D*, brittle cube-like appearance of rotted wood in lumber section. Normal sawmilling practice removes such affected areas from lumber during processing.

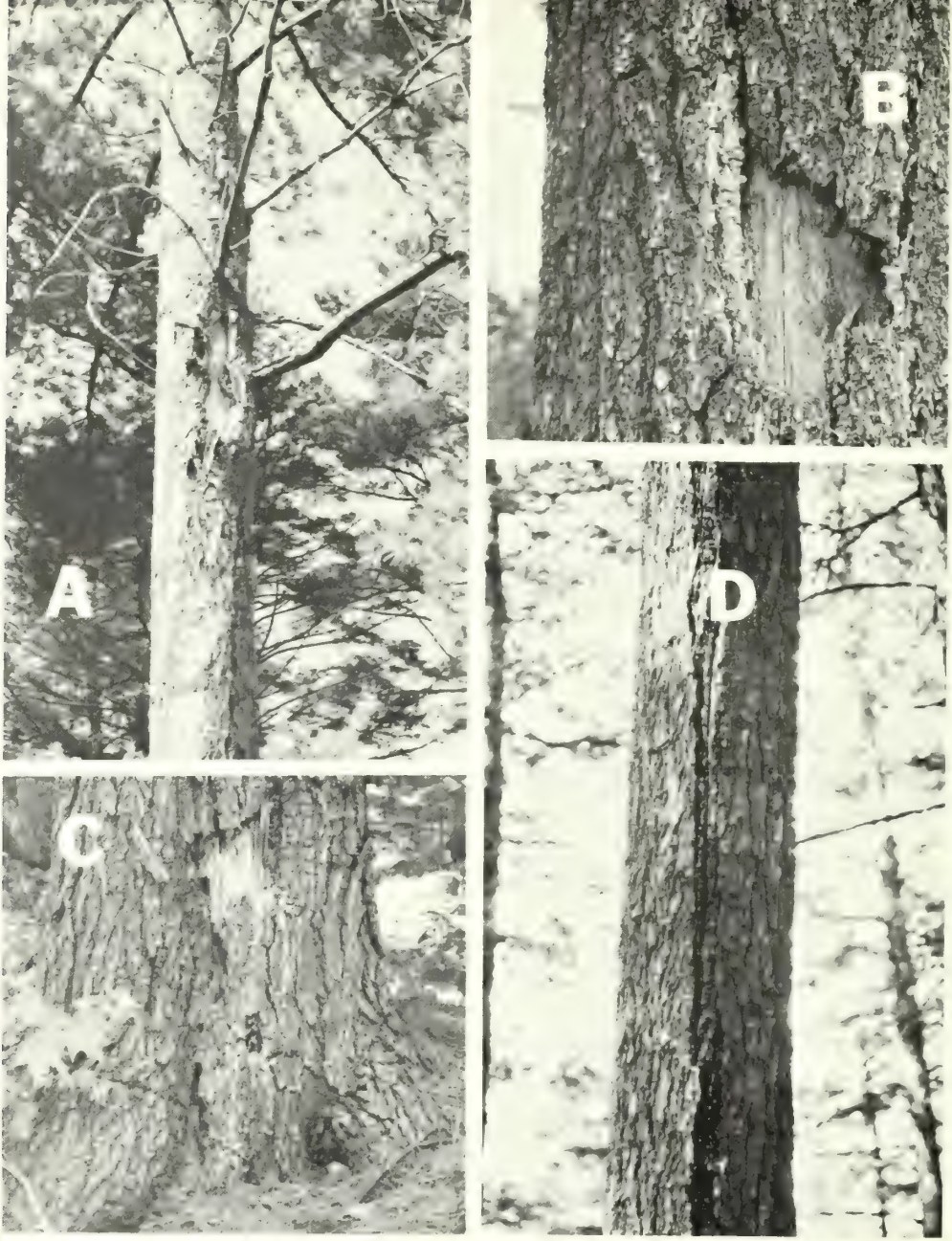


Figure 19.—Sound wounds and scars on eastern white pine logs or trees can usually be treated as scalable defects only. *A*, sun scald injury in lower crown of immature white pine—a common injury on severely exposed smooth-bark portion of upper stem. *B*, a shallow sound logging wound for which no scale deduction is necessary. *C*, a deeper sound wound for which scaling deduction is necessary. *D*, a lightning scar.

When brown cubical rot is present in a felled tree it is easily identified by inspecting the butt end of the butt log. Scale deduction is usually made for the entire cross-sectional area affected and for the estimated penetration up the log. Usually the affected portions of the resultant lumber are trimmed off, thereby causing no degrade in lumber, and thus no degrade in the log.

Other Scaling Defects

Sound open wounds and the scars or seams caused by injuries due to lightning, sun scald, logging, or other mechanical causes, and which show no evidence of rot, heavy stain, or insect damage in the underlying wood, may require a scale deduction, but are not considered as grading defects (fig. 19).

Splits caused by careless felling or bucking, or resulting from wind or ice damage, are scaling defects only. They require no reduction in grade. Forked trees, usually resulting from weevil injury, can be bucked into logs having minimum volume scale deduction due to bark seams (fig. 20). No further grade reduction is necessary. Standard Forest Service scaling procedures cover volume deductions for these common scaling defects.

Figure 20.—Bark seam in log, caused by forked tree.

Figure 21.—Blister rust infection (*Cronartium ribicola*) on the bole of a white pine may cause deformity requiring volume scale reduction.

Bole deformity caused by white pine blister rust (*Cronartium ribicola*) may sometimes require a scale deduction because of an abnormally small or flattened cross-section (fig. 21). Although heavy pitch accumulation is sometimes evident in the deformed portion of the log, it is not a grading defect.

IMPERFECTIONS DISREGARDED IN GRADING AND SCALING

The recognition and inclusion of *all* minor measurable log or tree imperfections that occasionally affect lumber quality would result in a reliable but impractical log- or tree-grading system. In addition, certain infrequent but serious blemishes still require additional research before consistent predictions can be made about their effects on lumber values.

The most serious but infrequent imperfections that can be disregarded include compression wood and pitch concentrations. Other frequent but insignificant imperfections include bird peck

and bark distortions. At present they are all disregarded in both grading and scaling.

Compression Wood

White pine logs cut from trees having lean in excess of 5 degrees usually contain areas of abnormal growth known as compression wood (fig. 22). Lumber cut from such logs is usually difficult to finish, and it developes severe warp in seasoning. Future tree-quality studies may result in reliable methods of

Figure 22.—Compression wood is common in leaning and crooked white pine trees. *A*, severe lean in a white pine tree. *B*, a cross-section of the leaning portion of the tree, showing eccentric growth rings with compression wood.

evaluating the effect of this defect. It is now disregarded in grading and scaling, although sweep that occurs in connection with tree lean is considered in grading.

Pitch Pockets

A relatively small volume of clear white pine lumber suffers degrade because of pitch accumulations. This can sometimes be detected from the log ends: pitch pockets are clearly defined accumulations of pitch following along annual rings of growth, or clearly defined areas of wood saturated with pitch. Because of the infrequency in occurrence of these imperfections and the difficulty in predicting their effect on lumber quality, they are disregarded in grading and scaling white pine logs. Pitch pockets greater than 3 inches in width are called pitch rings; they are considered the same as ring shake in grading.

Bird Peck

Bird peck refers to the small holes made by sapsuckers in the bark of the tree bole. These holes are usually found in horizontal bands or rows, but occasionally they are scattered over the smooth-bark area of a white pine tree. They may be deep enough to have injured the inner bark, thus causing a dimpled grain distortion and occasional flecks of ingrown bark in the underlying wood. However, they are not as serious as in hardwoods, where they result in darkly stained areas with ingrown bark.

Normally, sapsucker damage in white pine is in the knotty portion of the tree, where no further degrade results from the blemishes. Therefore they are disregarded in grading and scaling.

Bark Distortions

Breaks or alterations in the normal pattern of the bark, but which have no definite cause, are defined as bark distortions. They may result from deeply buried overgrown knots or small wounds (fig. 23). They are ignored in grading.

Figure 23.—Bark distortion on a mature white pine. In all probability this was caused by a deeply buried overgrown knot. Ignore it in grading.

■

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